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Concise report on world population monitoring, 2001: population, environment and development

Report of the Secretary-General

Summary

The present report has been prepared in accordance with the terms of reference of the Commission on Population and Development and its topic-oriented prioritized multi-year work programme, which was endorsed by the Economic and Social Council in its resolution 1995/55. The Commission, in its decisions 1999/1 and 2000/1, decided that the theme for the Commission at its thirty-fourth session in the year 2001 should be "Population, environment and development".

The report analyses recent information and policy perspectives on population, environment and development. The topics investigated in this report include: temporal trends in population, environment and development; government views and policies concerning population, environment and development; population size and growth, environment, and development; migration, population change, and the rural environment; health, mortality, fertility and the environment; and population, environment, and development in urban settings. The report also presents conclusions on these topics. Annex I deals with the availability and quality of data; and annex II deals with theories and frameworks for modelling the impact of population growth on the physical environment. The preliminary, unedited version of the full report is available as a working paper in document ESA/P/WP.164.

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Introduction

1. The twentieth century has been a century of unprecedented population growth, economic development and environmental change. From 1900 to 2000, world population grew from 1.6 billion to 6.1 billion persons (United Nations, 1999a). However, while world population increased close to 4 times, world real gross domestic product (GDP) increased 20 to 40 times (DeLong, 1998), allowing the world not only to sustain a fourfold population increase, but also to do so at vastly higher standards of living. Nevertheless, this rapid population growth and economic growth occurred unevenly throughout the world and not all regions have benefited equally from economic growth. Moreover, population growth and economic development occurred simultaneously with increasingly unsustainable utilization of the earth's physical environment.

2. Discussion of the interrelationships among population, environment and economic development long precedes the writings of Thomas Malthus in the early nineteenth century. Since ancient times, statesmen and philosophers have expressed opinions about such issues as the optimum number of people and the disadvantages of excessive population growth (United Nations, 1973a). The recurrent theme was the balance between population and natural resources conceptualized as means of subsistence or, more concretely, food and water. Not all theorists saw population growth in a negative light. In particular, mercantilist ideas in Europe during the seventeenth and eighteenth century saw the positive aspects of large and growing populations and favoured policies to encourage marriage and large families. Today, members of the Julian Simon school also emphasize the positive aspects of large and growing populations (Simon, 1981, 1990, 1996).

3. Deliberations and actions of the United Nations in the area of population, environment and development began at the founding of the Organization. This topic was the focus of an important debate, at the first meeting of the Population Commission (now the Commission on Population and Development) in 1947, and remained a recurrent topic in the work agenda of the Organization, at both the parliamentary and technical levels. In the early years of the United Nations, when world population was slightly more than a third of its present size, environmental issues in relation to population and development tended to be framed in terms of the natural resources needed to sustain population growth and economic development. In addition, issues of land availability and agricultural production were very prominent. Data on demographic and socio-economic trends in developing countries were exceedingly scanty at the time. The first studies concentrated on the situation of industrialized countries and on the impact of socio-economic development on demographic trends (that is to say, fertility, mortality and migration).

4. In the 1960s, there was an increased awareness that global population growth had reached unprecedentedly high levels, a situation that many studies and debates treated as a matter of grave concern. A report of the Secretary-General entitled "Problems of the human environment" cited the "explosive growth of human populations" as first among the portents of a crisis of worldwide scope concerning the relation between man and his environment (United Nations, 1969). That report was a crucial step towards the convening by the United Nations of the Conference on the Human Environment, Stockholm, June 1972, which was the first world intergovernmental conference on the protection of the environment.

5. The outcome of the Conference — the Declaration of the United Nations Conference on the Human Environment (United Nations, 1973b, chap. I) and the Action Plan for the Human Environment (ibid., chap. II) — constituted the basis for activities of the United Nations system on environmental issues during the 1970s and 1980s. The Declaration affirmed (para. 5) that "the natural growth of population continuously presents problems for the preservation of the environment, and adequate policies and measures should be adopted, as appropriate, to face these problems". However, the Declaration also proclaimed that "of all things in the world, people are the most precious", noting that "it is the people that propel social progress, create social wealth, develop science and technology and, through their hard work, continuously transform the human environment". Further emphasizing this positive note, the Declaration went on to assert that "along with social progress and the advancement of production, science and technology, the capability of man to improve the environment increases with each passing day". The Stockholm Conference did not take a position on the global effects of population growth, recognizing that in certain areas the growth of population could frustrate development efforts, while in other areas population densities were too low to permit economic efficiency.

6. The first global, intergovernmental population conference was held in Bucharest in 1974. The World Population Plan of Action adopted at the United Nations World Population Conference (United Nations, 1975, chap. I) framed the environmental question in terms of per capita use of world resources. The Plan urged developed countries to adopt appropriate policies in population, consumption and investment, bearing in mind the need for fundamental improvement in international equity.

7. Environmental issues were not particularly prominent in the overall agenda of the second global conference on population, the International Conference on Population, held in Mexico City in 1984. However, the Conference recommendations for the further implementation of the World Population Plan of Action (United Nations, 1984, chap. I, sect. B (III and IV)) went beyond the outcome of Bucharest by framing environmental issues as a dimension of the population-development relationship on the global scale, urging all countries in which there were imbalances between trends in population growth and resources and environmental requirements, to implement policies to redress such imbalances. Using language that was to become the cornerstone of the developmental paradigm for the 1990s, the Conference emphasized that the formulation of national population goals and policies must take into account the need for long-term environmentally sustainable economic development (ibid., sect. B, para. 8).

8. The United Nations Conference on Environment and Development held in Rio de Janeiro, Brazil, in 1992 was a milestone in the evolution of an international consensus on the relationships among population, development and environment, based on the concept of *sustainable development* articulated a few years earlier by the World Commission on Environment and Development. The Commission had defined sustainable development as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987, overview entitled "From one earth to one world", sect. I, p. 8). The Rio Declaration on Environment and Development (United Nations, 1993a, resolution 1, annex I) identified population policies as an integral element of sustainable development.

Principle 8 of the Rio Declaration stated that "to achieve sustainable development and a higher quality of life for all people, States should reduce and eliminate unsustainable patterns of production and consumption and promote appropriate demographic policies". Chapter 5 of Agenda 21 (ibid., annex II) covered demographic dynamics and sustainability and stated that "the growth of world population and production combined with unsustainable consumption patterns places increasingly severe stress on the life-supporting capacities of our planet" (para. 5.3).

9. These issues were revisited at the International Conference on Population and Development held in Cairo in 1994. Forging a balance among population, sustained economic growth and sustainable development was the central theme of the Cairo conference. The Programme of Action of the International Conference on Population and Development adopted by the Conference (United Nations, 1995, resolution 1, annex) noted "the growing awareness that population, poverty, patterns of production and consumption and the environment are so closely interconnected that none of them can be considered in isolation" (para. 1.5). Population factors were seen, sometimes, as inhibitors of sustainable development: "demographic factors combined with poverty and lack of access to resources in some areas, and excessive consumption and wasteful production patterns in others, cause or exacerbate problems of environmental degradation and resource depletion and thus inhibit sustainable development" (para. 3.25); and "pressure on the environment may result from rapid population growth, distribution and migration, especially in ecologically vulnerable ecosystems" (para. 3.26). The Programme of Action states that "slower population growth has in many countries bought more time to adjust to future population increases. This has increased those countries' ability to attack poverty, protect and repair the environment, and build the base for future sustainable development. Even the difference of a single decade in the transition to stabilization levels of fertility can have a considerable positive impact on quality of life" (para. 3.14). The Conference recognized the "crucial contribution that early stabilization of the world population would make towards the achievement of sustainable development" (para. 1.11).

10. The first review and appraisal of the implementation of Agenda 21 took place as a special session of the General Assembly in June 1997. The Programme for the Further Implementation of Agenda 21 (Assembly resolution S-19/2, annex) was adopted. The Programme noted that population growth rates had been declining globally, and that the trend was projected to lead to a stable world population in the middle of the twenty-first century, and that there was a need to recognize the critical linkages between demographic trends and factors of sustainable development. The second review and appraisal of Agenda 21 (the ten-year review and appraisal of the implementation of the outcome of the United Nations Conference on Environment and Development) will take place in 2002.

11. The twenty-first special session of the General Assembly, convened in 1999 to review and appraise the implementation of the Programme of Action of the International Conference on Population and Development, also addressed environmental concerns (see Assembly resolution S-21/2, annex). In particular, it reaffirmed that "early stabilization of world population would make a crucial contribution to realizing the overarching objective of sustainable development" (ibid., para. 7).

I. Temporal trends in population, environment and development

Population

12. The twentieth century witnessed an extraordinary growth of world population — from 1.6 billion to 6.1 billion people, 80 per cent of the increase having occurred since 1950 (figure I). Rapid population growth was triggered by dramatic reductions in mortality, especially in the less developed regions, where average life expectancy at birth increased by 23 years during the second half of the century. As a result, world population has increased by two and one half times since 1950, with the global rate of growth peaking at 2.04 per cent per year during the late 1960s. Annual increments of 86 million persons during the late 1980s were the largest in history. The world added its most recent billion people in just 12 years (from 1987 to 1999), the shortest period in history for an increase of 1 billion.

13. Owing to declining fertility, however, global population growth has decreased significantly. Between 1965-1970 and 2000-2005, world fertility declined from 4.9 births to 2.7 births per woman. Estimates suggest a current growth rate of 1.3 per cent per year, and an annual net addition of 78 million people. Despite fertility declines to relatively moderate levels, the number of births continues to increase, owing to the growth in the number of women of childbearing age. While in 1965-1970 the average annual number of births in less developed regions was 102 million, today this number is estimated at 117 million.

14. World population is expected to continue growing for the next 200 years (United Nations, 2000a). Based on the medium-fertility variant, which assumes replacement-level fertility of 2.1 children per woman, global population is projected to reach 9 billion people in 2054 and 10 billion in 2183, before nearly stabilizing at just above 10 billion around 2200 (table 1). However, long-term population size is sensitive to small but sustained deviations in fertility levels (United Nations, 2000b). For example, a low-fertility scenario in which fertility is assumed to be half a child lower than in the medium-fertility scenario results in a population that declines to 3.2 billion in 2150. In contrast, a high-fertility scenario in which fertility is half a child higher than in the medium-fertility scenario produces a population of 24.8 billion in 2150 (figure I).

Table 1
World population milestones

Population	*Year*
	World population reached
1 billion in	1804
2 billion in	1927 (123 years later)
3 billion in	1960 (33 years later)
4 billion in	1974 (14 years later)
5 billion in	1987 (13 years later)
6 billion in	1999 (12 years later)
	World population may reach
7 billion in	2013 (14 years later)
8 billion in	2028 (15 years later)
9 billion in	2054 (26 years later)
10 billion in	2183 (129 years later)

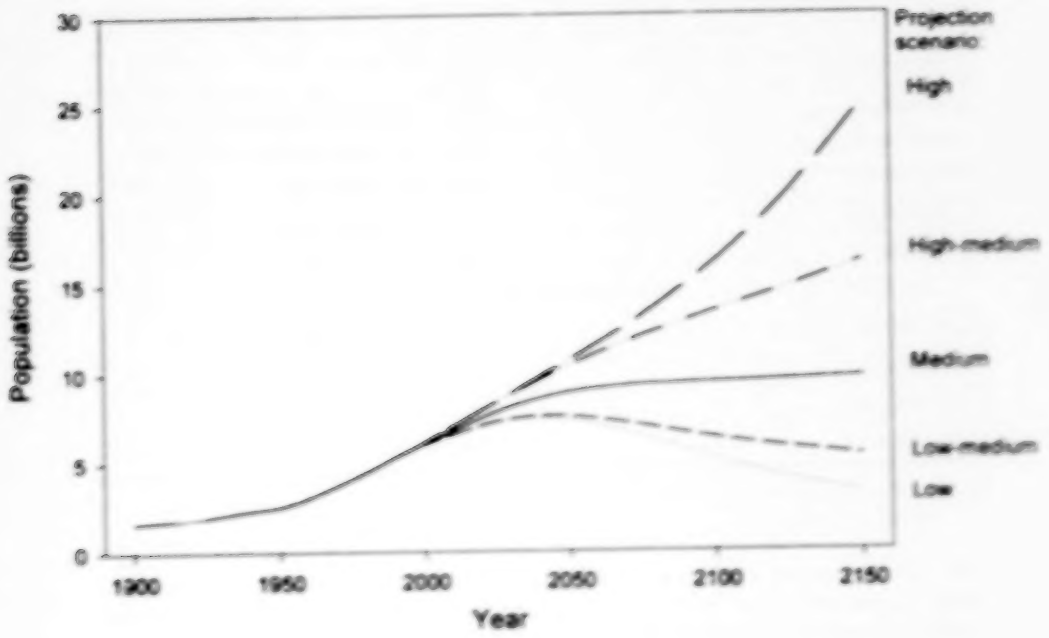
Source: Population Division of the United Nations Secretariat, "The world at six billion" (ESA/P/WP.154).

15. Because world regions are at varying stages in the transition from high to low rates of mortality and fertility, their growth paths differ, resulting in significant shifts in the geographical distribution of population. In 1970, 68 per cent of the world population resided in the less developed regions; at present, 80 per cent reside there. Of the 78 million people added to the world each year, 95 per cent live in the less developed regions.

16. The impact of international migration on population growth for more developed regions has been increasing. The 35 million net migrants absorbed by Western market economies between 1970 and 1995 accounted for 28 per cent of their combined population growth, while the loss of those migrants reduced population growth in the rest of the world by under 2 per cent. Worldwide, the number of persons who have moved to another country has risen to over 125 million migrants (United Nations, 1999a).

17. Another relevant, vital population trend is urbanization. Whereas in 1950, 30 per cent of the world were urban-dwellers, by 2000 the proportion had risen to 47 per cent. The urban population is projected to equal the rural population by 2007. With increasing urbanization, mega-cities have become more numerous and considerably larger in size. In more developed regions, the size of the rural population began declining well before 1950; in contrast, in less developed regions, the rural population doubled between 1950 and 2000.

Figure I
Growth of world population since 1900 and projections to 2150

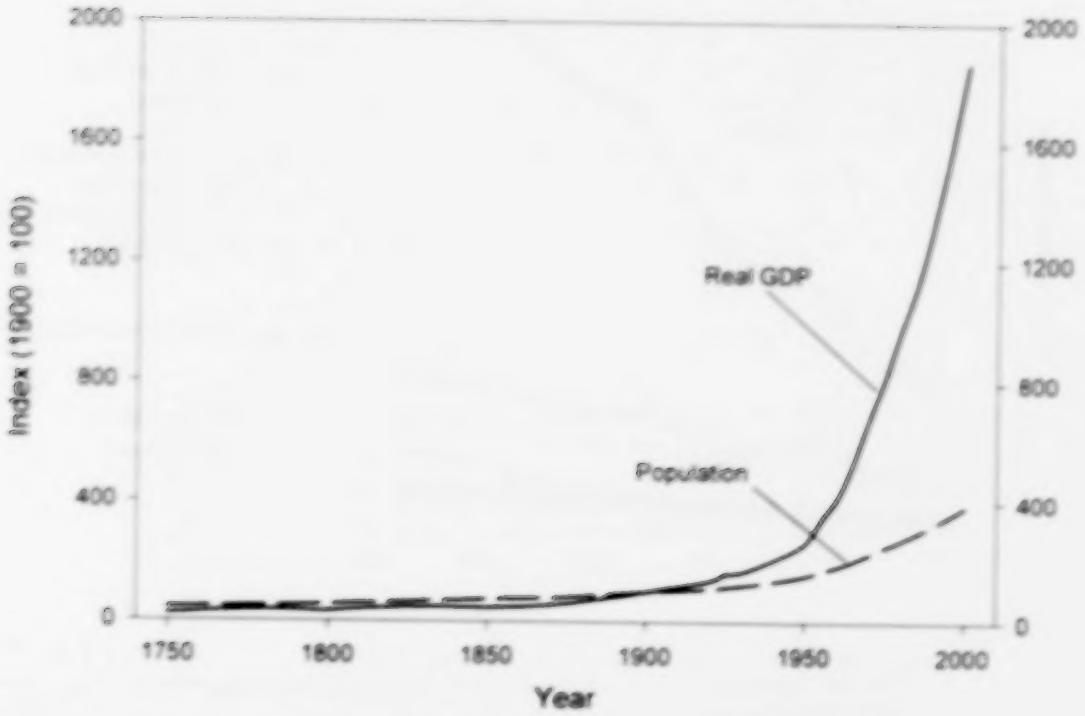


Sources: Long-Range World Population Projections: Based on the 1998 Revision (United Nations publication, Sales No. E.00.XIII.8), and Population Division of the United Nations Secretariat, "The world at six billion" (ESA/P/WP.154).

Economic growth and poverty

18. The enormous expansion in the global production of goods and services driven by technological and social and economic changes has allowed the world to sustain both much larger populations and vastly higher standards of living than ever before in history. The two most salient characteristics of economic growth in the latter half of the twentieth century have been its unprecedented pace and its uneven distribution between countries and regions. Between 1950 and 2000, world GDP at constant prices expanded eightfold (International Monetary Fund, 2000). During the same period, world population grew from 2.5 billion inhabitants in 1950 to 6.1 billion in 2000. Because of the accelerating tempo of technological progress, output growth has remained well ahead of population growth (figure II), inducing a threefold increase in per capita GDP.

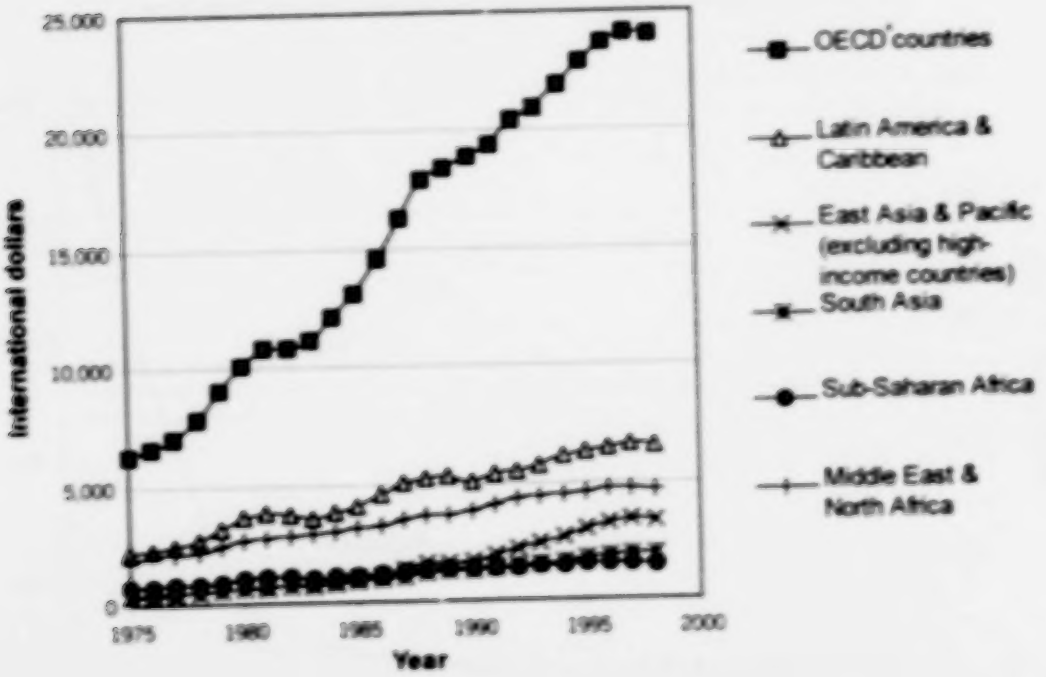
Figure II
World gross domestic product (GDP) and population growth, 1750-2000



Source: International Monetary Fund, *World Economic Outlook 2000* (Washington, D.C., 2000), based on J. Bradford DeLong, *Estimating World GDP, One Million B.C.–Present* (Berkeley, California, Department of Economics, University of California at Berkeley, 1998).

19. The benefits accruing from the unprecedented growth of the world economy have been uneven. Aggregate data conceal the widening disparities in income over time (figure III). Although the per capita GDP of the wealthiest quarter of world population climbed sixfold over the century, per capita income for the poorest quarter of world population grew less than threefold (International Monetary Fund, 2000). The percentage of the world's population living in absolute poverty (living on less than one United States dollar per day) declined from about 28 per cent in 1987 to 24 per cent in 1998. However, the absolute number of poor has changed little and in 1998 amounted to 1.2 billion people (World Bank, 2000). Poverty is related to a host of factors, including income, health and education.

Figure III
Per capita income in major world regions, 1975-1998



Source: World Bank, *World Development Indicators 2000*, CD-ROM.

Note: Per capita GDP is expressed in international dollars using purchasing power parity (PPP) conversion rates.

* Organisation for Economic Cooperation and Development.

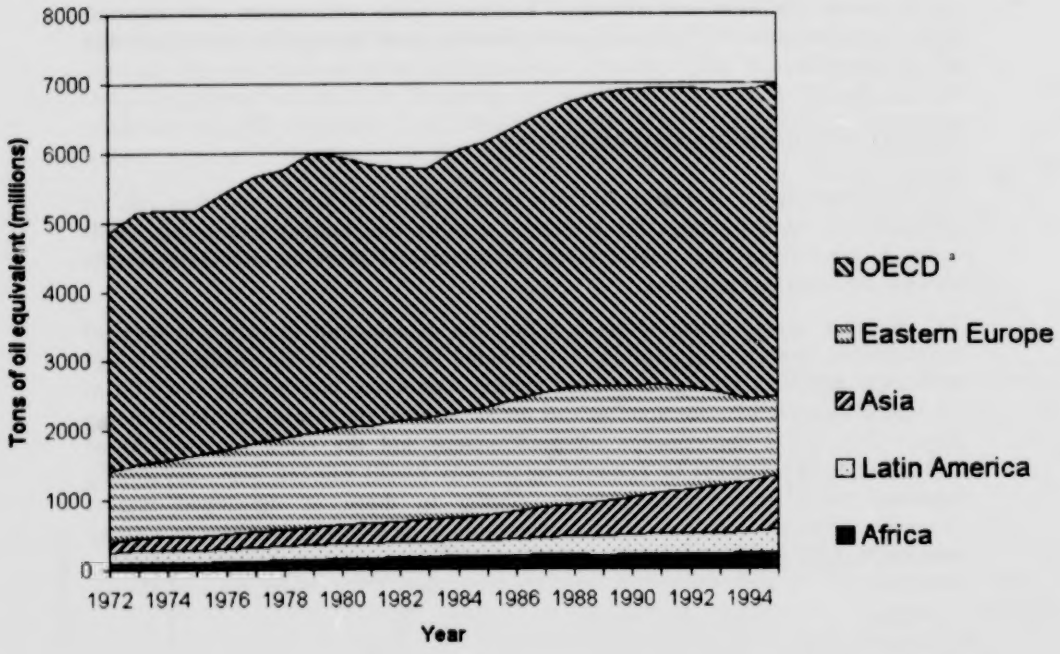
20. In recent years, development efforts have shifted from the traditional focus on per capita income to improvements in health, education and sanitation as characteristics of development. For example, many low-income countries have achieved substantial improvements in the quality and length of life. These achievements reflect successes at providing basic social services such as education and access to safe water and sanitation. These successes have in turn contributed to reducing infant and child mortality and illiteracy, and raising life expectancy and school enrolments.

Energy consumption and emissions

21. The importance of energy and raw materials derives from their dual role of providing the underpinnings for economic activity and human well-being, while acting as the driving force behind many environmental concerns, including climate change, acid rain and pollution.

22. Because energy consumption is a function of economic growth and level of development, energy consumption is distributed unequally in the world. Although their share has been falling, developed market economies, constituting one fifth of the world's population, consume almost 60 per cent of the world's primary energy (figure IV). As a consequence of development and the rapid replacement of traditional energy sources by commercial (mainly fossil) sources, some developing countries have consumption patterns similar to those of developed market economies. Nevertheless, per capita consumption in developing countries as a group remains far below that of developed market economies.

Figure IV
Primary energy use in major world regions, 1972-1995



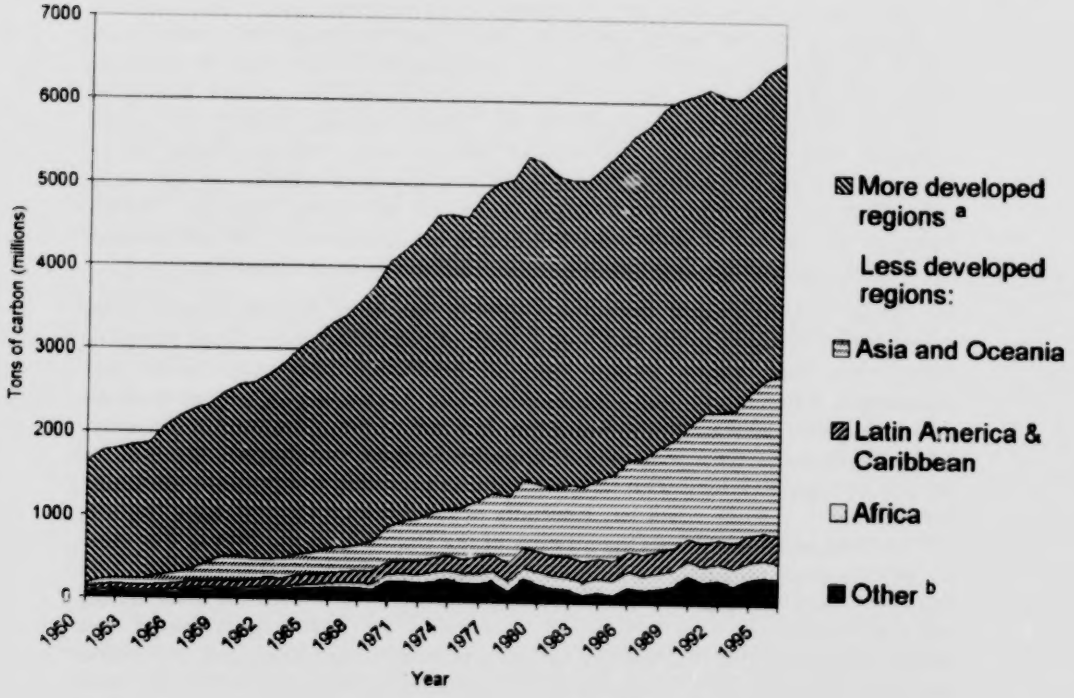
Source: International Energy Agency, *Energy Balances of Non-OECD Countries 1996-1997* (Paris, 1999).

[a] Organisation for Economic Cooperation and Development.

23. The use of fossil fuels has led to substantial growth in global emissions of carbon dioxide (CO_2) and the build-up of greenhouse effects, contributing to global warming. Since 1751, over 265 billion tons of carbon have been released to the atmosphere, one half of these emissions having been produced since the mid-1970s (Marland and others, 1999). Annual global emissions of CO_2 from the burning of fossil fuels have quadrupled since 1950 (figure V). The highest per capita CO_2 emissions are in North America, which is followed by Europe where such emissions are less than one half those of North America (ibid.). Continuation of these trends poses serious risks of global warming, inducing of a possible rise in sea levels, flooding of low-lying coastal areas, spread of vector-borne diseases and reductions in agricultural yields.

Figure V

Carbon dioxide (CO_2) emissions from fossil fuels and cement production, 1950-1996



Source: Gregg Marland and others, Global, regional and national annual CO_2 emissions from fossil-fuel burning, hydraulic cement production and gas flaring: 1751-1996 (Internet: http://cdiac.eds.ornl.gov/ftp/ndp030/ndp030.html).

[a] Including the former Union of Soviet Socialist Republics.

[b] Emissions from bunker fuels and other emissions for which the country of final use cannot readily be determined.

24. The magnitude of future carbon emissions depends on many factors, including global energy demand, the pace of economic development, the introduction of energy-saving technologies and the degree of shift away from fossil fuels. Models suggest that immediate stabilization of atmospheric CO_2 concentrations at present levels can be achieved only if emissions are immediately slashed by at least 50 per cent and further reduced thereafter (United Nations Environment Programme, 1999). Because of the inertia of climate systems, even with stabilization of emissions, global warming and the rise of sea levels could continue for many years.

Agriculture, food and land use

25. The persistence of undernutrition and food insecurity in some areas of the world, and the increasing scarcity and unsustainable utilization of agricultural and other environmental resources, have dominated the global assessment of food and agriculture prospects. World agricultural production has outpaced population growth, and the real price of food has declined. The green revolution that began in the 1960s enabled some developing countries to dramatically boost food production by introducing modern agricultural techniques. Over the period 1961-1998, world food for human consumption, per capita, increased by 24 per cent. A sufficient amount of food is being produced to adequately nourish the world's population (Food and Agriculture Organization of the United Nations, 2000a). Yet, recent estimates show that some 790 million persons were undernourished as of 1995-1997, owing to poverty, political instability, economic inefficiency and social inequity (Food and Agriculture Organization of the United Nations, 1999a). Although the number of undernourished people has decreased by 40 million since 1980, some countries are experiencing serious declines in food availability.

26. More recently, world agricultural growth has been slowing down. Many attribute this slowdown to the declining growth of population and reduced economic demand for food; others discern signs of production constraints which may ultimately threaten world food security (Food and Agriculture Organization of the United Nations, 2000a; World Resources Institute, 1996; Worldwatch Institute, 2000). While world food production is projected to meet consumption demands for the next two decades, long-term forecasts indicate persistent and possibly worsening food insecurity in many countries, especially in sub-Saharan Africa (United Nations, 1997a; Food and Agriculture Organization of the United Nations, 2000a). For most of history, food production has been increased mainly by expanding the area cultivated; but in the past few decades, rising crop yields have been the main factors and this trend is expected to continue. Constraints on expanding cultivated land include the scarcity of high-quality agricultural land, competition from alternative land uses, and the risk of environmental degradation of marginal cultivated lands and forests.

27. Although direct human consumption of grain is the most efficient use of food supplies, more land in developing countries is now used for growing grain feed, fodder and forage for livestock, as dietary choices reflect a growing preference for meat and dairy products. Development and population growth are claiming increasing shares of land for housing, industry and infrastructure. The major cause of land loss, however, is degradation. Although estimates of the global extent of loss of land productivity range widely, serious erosion has often followed extension of farmland to slopes of hills, and salinization of soil is a serious problem in some

areas. Long-term global warming and climate change could also threaten the high-quality land of some countries through sea-level rise or deterioration in agro-ecological conditions.

Water

28. An adequate and dependable supply of fresh water is essential for health, food production and socio-economic development. Though more than two thirds of the planet is covered with water, less than 0.01 per cent is readily accessible for direct human use (United Nations, 1997b). Moreover, no more of this renewable fresh water is available today than existed at the dawn of human civilization. As a result, the size of a country's population and the speed at which it grows help determine the onset and severity of water scarcity. Although recent declines in population growth have improved the outlook for future water availability, the problems associated with water scarcity will continue to mount as the size of the world's population increases.

29. Currently, humans are using about half the fresh water that is readily available. Fresh water is distributed unevenly over the globe, and already nearly half a billion people are affected by water stress or serious water scarcity, while many more are experiencing moderate stress. Given current trends, as much as two thirds of world population in 2025 may be subject to moderate-to-high water stress (United Nations, 1997b). Many countries facing water scarcity are low-income countries that have a rapidly growing population, and are generally unable to make costly investments in water-saving technologies.

30. About 300 major river basins, and many groundwater aquifers, cross national boundaries (United Nations, 1997b). Therefore, the need for cooperative efforts will persist, particularly in areas facing water shortages, and wherever pollution is carried downstream across national boundaries.

31. Estimates indicate that over 1 billion people lack access to safe drinking water and two and a half billion lack adequate sanitation, and these factors contribute to the deaths of more than 5 million people, of whom more than half are children (United Nations, 2000c).

Forests and biodiversity

32. The number of plant and animal species inhabiting the planet is not accurately known. Nearly 2 million species have been identified, but estimates of the number yet to be described range from 10 million to 30 million (United Nations Environment Programme, 1995). Ecosystems of all kinds are under pressure worldwide. Coastal and lowland areas, wetlands, native grasslands, and many types of forests and woodlands have been particularly affected or destroyed. While forests decreased by about 5 per cent between 1980 and 1995, the rate of deforestation has been declining slightly (Food and Agriculture Organization of the United Nations, 2000b). Additional threats confront fragile aquatic habitats, including coral reefs and freshwater habitats, which face an array of assaults from dams to land-based pollution to destructive fishing techniques.

33. Over the past 150 years, deforestation has contributed one third of the atmospheric build-up of CO_2 and it is a significant factor in the loss of species and critical ecosystem services (Intergovernmental Panel on Climate Change, 2000). Since the beginnings of agriculture 10,000 years ago, by some estimates, almost half of the earth's forests have been converted to farms, pastures and other uses, and only one fifth of original forest remains in large, relatively natural ecosystems. Forested areas, including forest plantations as well as natural forests, occupied about one fourth of the world's land area in 1995. Tropical rain forests are important for the quantity and diversity of life they support. They cover only 7 per cent of the earth's land area, but contain at least 50 per cent of terrestrial species (Food and Agriculture Organization of the United Nations, 1999b).

34. The influences of forests and biodiversity are global, reaching far beyond national borders, in both space and time. Therefore, international cooperation is essential in order to better integrate environmental issues into global, regional and national decision-making processes.

II. Government views and policies concerning population, environment and development

35. During the 1990s, an increasing number of Governments became seriously concerned about environmental problems, whether of a domestic nature or, less frequently, of a cross-boundary nature. At the 1992 United Nations Conference on Environment and Development, a consensus was established that population, the environment and development were inextricably linked. This consensus view was reaffirmed at the 1994 International Conference on Population and Development. In addition, reports and statements produced by Governments and non-governmental organizations for the first quinquennial review and appraisal of the implementation of Agenda 21 and of the implementation of the Programme of Action of the International Conference on Population and Development provide a solid basis on which to assess how far the various stakeholders have gone in operationalizing the linkages among population, environment and development.

Governments' views on environmental issues in the context of population policies

36. According to the Eighth United Nations Inquiry among Governments on Population and Development (United Nations, forthcoming), the impact of population trends on the amount of fresh water, on water pollution and on the deterioration of the urban environment in both the more developed and the less developed regions of the world, as well as on air pollution in the more developed regions, is among the issues that raise the greatest concern among Governments. Some countries refer to national environmental issues while others address global issues. However, it is often unclear whether the replies reflect the importance that the Governments attach to environmental issues per se apart from population as an intervening factor, or the importance that the Governments attach to population as a contributing factor to environmental change.

37. Countries in the more developed regions and those in the less developed regions differ significantly with regard to their degree of concern over these issues.

In the more developed regions, less than one country in two expresses deep concern over population linkages with air pollution and the deterioration of the urban environment, and one country in three over linkages between population and the quality and quantity of water resources. In the less developed regions, in contrast, 73 per cent of Governments make reference to population trends in relation to water pollution and 63 per cent in relation to the amount of fresh water. A large majority of countries — 65 per cent — also refer to the linkage between population growth and the deterioration of the urban environment. Sixty per cent of countries mention the linkage between rural population growth and density and the degradation of agricultural land and forests.

Population dynamics in the context of environmental policies

38. Since the convening of the United Nations Conference on Environment and Development in 1992, over 100 countries have adopted national sustainable development strategies or national environmental action plans. These processes have largely focused on setting national environmental priorities, devising the best private-public intervention mixes in relation to those priorities, and involving the public. Although policy implementation has been lagging behind policy formulation, as evidenced by the large majority of country reports prepared for the first quinquennial review and appraisal of Agenda 21, national environmental policy instruments provide a unique framework within which to obtain a sense of the salience of population issues in the context of environmental policies. On an operational level, the linkages between population dynamics and the environment are probably best addressed by local environmental management initiatives.

39. In national environmental strategies and action plans prepared by countries in the more developed regions, little reference is made to demographic dynamics. In contrast, national policy frameworks devised by countries in the less developed regions call for the necessity of preventing poverty-driven environmental degradation in the context of rapid population growth and improving the environmental conditions of the poor. However, generally there is little elaboration. Policies and programmes that address human settlements and land management as well as, to a lesser extent, agriculture and forestry provide further insights. In the less developed regions, public authorities' concern over population dynamics in relation to environmental degradation essentially arises from high demographic concentration and growth in specific geographical zones. Expanding slum settlements in large cities and frontier migration, in particular, are issues that are often considered critical from an environmental policy viewpoint.

40. The policy approach taken by the great majority of countries favours integrated urban and rural development programmes that adapt to, rather than intend to modify, population dynamics. Unlike policies adopted in the 1970s and 1980s, there are very few attempts being made to contain urban growth and to relocate population to new, secondary cities. Land management policies and human settlement programmes typically include measures to upgrade infrastructure and services, control the location of new housing and, in general, ensure sound land use. Most such programmes are designed to mitigate the negative effects of an earlier lack of planning.

41. In reporting on these programmes, several Governments point to the lack of sufficient, accurate and up-to-date data, ranging from basic demographics to land conversion and infrastructure deployment patterns, as a serious impediment to designing better land management and human settlements policies. While continuous improvement in data quality and availability allows an increasing number of countries to include population estimates and projections in their national environmental plans, data availability and the resources required for their integration at the micro-scale level are rarely available. Also demographic statistics are called upon to illustrate the challenges lying ahead and the sheer magnitude of the work to be accomplished. By and large, demographic factors are viewed as exogenous rather than as policy variables in the context of land management and human settlements.

42. While few Governments attempt to contain rural-urban migration directly, most have developed measures to correct the urban bias and equalize development opportunities within the country. Strategies for poverty alleviation in agriculture focus on reforming land tenure systems and ensuring access to land as well as on diversifying agricultural production and promoting sustainable farming practices while avoiding encroachment on environmentally sensitive areas. Property regimes are seen as both cause of, and solution to, poverty-driven environmental degradation. The promotion of sustainable practices in the areas of farming, fishing and forestry is increasingly seen as critical in securing and/or restoring a basis for economic activities, and therefore as offering development opportunities to people living in rural areas. Environmental policies and programmes are increasingly designed and implemented through participatory processes that involve civil society. Most Governments and donors believe that participatory management through community involvement at the local level is essential to ensure sustainability and to build local capacity. Taking local knowledge and traditional technologies into account is also increasingly seen as necessary. The promotion of sustainable practices is therefore carried out primarily within the framework of community-based initiatives with international technical and financial assistance. Activities range from awareness-creation to building local capacity in the management of natural resources and support to non-agricultural supplemental income-generating activities. Local Governments in South America, South-eastern and South-central Asia have been relatively proactive in implementing natural resource management projects.

Public opinion regarding the environment

43. Political mainstreaming of environmental issues has led Governments to make commitments enabling civil society participation in environmental policy processes and to encourage firms to develop a sense of corporate social responsibility. Gaining a better understanding of the public's attitudes and expectations vis-à-vis the environment has become an integral part of public policy-making as well as, lately, business strategies. A striking feature of public opinion surveys is the lack of reference to demographic dynamics in relation to the environment in either the questionnaires used or the spontaneous replies of respondents.

44. Findings from recent international surveys, as well as from several national and local surveys, provide a consistent and contrasting picture of how citizens of both developed and developing countries perceive environmental issues, keeping in mind the limits inherent in any interpretation of public opinion polls. First and

foremost, survey results point to the environment's being a pressing concern of citizens in both the more developed and less developed parts of the world, together with issues such as unemployment/economic hardship, violence and health problems. According to the Environmental Monitor, a significant proportion of people in all 27 countries surveyed have at least "a fair amount of concern" about the environment (Environics International, 1999). In the countries of the European Union (EU), almost one inhabitant in two (46 per cent), on average, has serious concerns about the environment (European Commission, 1999). Furthermore, comparison with results of past surveys clearly shows that environmental concerns have been rising, particularly in developing countries. In urban India, 27 per cent of respondents to the Environmental Monitor volunteered an environment-related response when asked about the most important problems they faced in 1999, as compared with 6 per cent in 1992. Only in Canada and the United States of America, has concern with the environment been somewhat lower than the very high level observed in 1992. The belief that high environmental standards pertain only to the rich country consumers' agenda is therefore not supported by recent public opinion polls.

45. Whereas environmental concern is becoming universal, there are significant cross-regional differences in people's assessment of the overall state of their local and national environment. In all countries of the EU, inhabitants express satisfaction with the current state of their environment and have "not much reason to complain" about environmental issues such as air pollution, quality of water, waste disposal, noise and traffic problems. However, they chiefly worry about a serious deterioration of the environment in the future. In contrast, close to 80 per cent of inhabitants of Eastern European countries such as Hungary, Poland, the Russian Federation and Ukraine express major dissatisfaction with the current state of the environment in their country. In the less developed regions, similar levels of dissatisfaction are observed in many countries such as Armenia, Colombia, the Dominican Republic, Ecuador, Chile, Kazakhstan, the Republic of Korea, Pakistan and Peru. Only in Malaysia and Singapore do respondents find the environment satisfactory — 75 per cent and 91 per cent, respectively, according to the Gallup Millennium Survey (Gallup International Association, 1999).

46. Clearly, underpinning the public's perception of the environment and policy expectations are worries over the health consequences of water and air pollution. In almost all countries surveyed in the less developed regions, nearly one person in two believes that local pollution has affected his or her personal health and will harm the health of his or her children. Concerns over the impact of water and air, as well as soil pollution trends on the future health of the population, are also driving opinion in the more developed regions. Also, a striking regional feature, obviously influenced by the aftermath of the Chernobyl catastrophe, is the serious concern expressed by approximately one inhabitant in two in Eastern Europe over the health impact of accidents with nuclear energy. Somewhat surprisingly, large minorities of people consistently express concern, across surveys, over more abstract issues such as climate changes. Indeed, climate change has received a great deal of media attention in the recent past, particularly in the context of the adoption and implementation of the Kyoto Protocol (United Nations, 1998) to the United Nations Framework Convention on Climate Change (United Nations, 1992).

47. Whereas the public seems to perceive that the environmental protection efforts of both the public and the private sector are insufficient, in almost all countries, majorities or near majorities of citizens look forward to Governments' and businesses' renewed and strengthened action on the very issues that are at the core of their concern: pollution and, to a lesser extent, climate change. This expectation of the public is conveyed with a sense of urgency: action is needed now and policy should be based on deterrence. Enforcement of stronger environmental laws and regulations and, to a lesser extent, strict application of the "polluter pays principle" are widely considered the best ways to reduce industrial pollution.

Integration of population and environmental policies

48. Since the 1992 United Nations Conference on Environment and Development and the 1994 International Conference on Population and Development, major efforts have been devoted to formulating and implementing new policies in the areas of both population and the environment. However, the integration of population, development and environmental plans has progressed little. Several factors might have contributed to this lack of progress. For example, existing administrative arrangements are not conducive to policy coordination. A majority of countries have a ministry in charge of environmental planning and, at least, one agency responsible for the coordination of population policies and programmes. However, few countries have located the population unit within the ministry of the environment. In a significant number of countries, population issues are the responsibility of the ministry of health. On the other hand, the ministry in charge of population issues does not, in many cases, participate in the national bodies for coordination and follow-up of environmental plans.

III. Population size and growth, environment and development

49. Concerns about population and the environment have been evolving over time (see table 2). Beginning in the late 1940s and 1950s, environmental concerns focused almost exclusively on what was felt to be the negative impact of population growth on non-renewable natural resources and food production. Virtually no attention was given to environmental side effects. During the 1960s and 1970s, the focus was widened to incorporate the by-products of production and consumption, such as air and water pollution, waste disposal, pesticides and radioactive waste. By the 1980s and into the 1990s, a new dimension was added, encompassing global environmental changes, including global warming and ozone depletion, biodiversity, deforestation, migration and new and re-emerging diseases.

50. Many attempts have been made to estimate the number of people that the Earth can support, or human "carrying capacity". Most estimates are based on an assumption that human populations are constrained by one or more limiting factors, most commonly the amount of food that can be grown. In addition, most estimates recognize that "ecological concepts of carrying capacity must be extended to allow for the role of technology in enhancing nature's productivity. Most recognized that culturally and individually variable standards of living, including standards of environmental quality, set limits on population size well before the physical requirements for sheer subsistence" (Cohen, 1995, p. 232). The estimates of Earth's carrying capacity range from under 1 billion to more than 1,000 billion persons (figure VI). Not only is there an enormous range of values, there is also no tendency for the values to converge over time. This is worth noting, as it might be expected that, with the improvement in knowledge of Earth's biological and physical systems, there should be an approach to a consensus regarding Earth's carrying capacity for mankind. Yet, while few would dispute that population growth must come to a halt eventually, there is no consensus on where the limits lie. At the same time, it is worth noting that the world's population has already entered into the zone where many of the carrying-capacity estimates are found. Around two thirds of the estimates fall in the range of 4 to 16 billion persons, and the median value is about 10 billion, or near the size where world population is projected to eventually stabilize, according to the Population Division's medium-variant scenario (United Nations, 2000a).

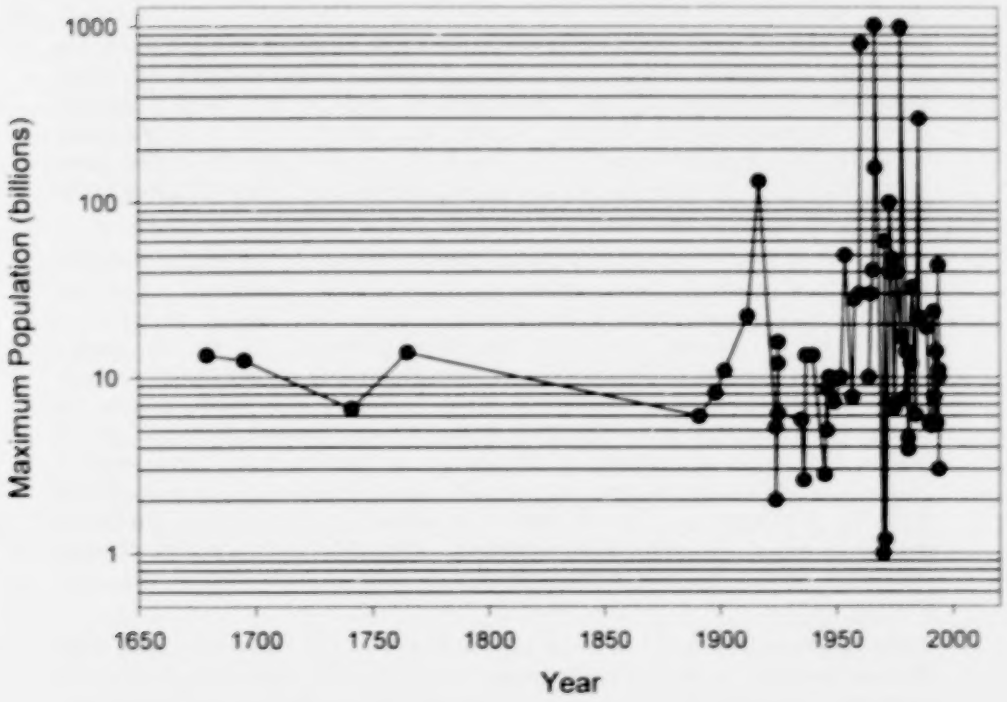
Table 2
Evolution of environmental concerns, 1940s to the present

Wave	*Date*	*General concern*	*Specific issues*	*Document*
First	1940s-1950s	Limited natural resources	Inadequate food production Depletion of non-renewable resources	United Nations report on population and resources (E/CN.9/55)
Second	1960s-1970s	By-products of production and consumption	Air and water pollution Waste disposal Radioactive/chemical contamination	Declaration of the United Nations Conference on the Human Environment World Population Plan of Action of the United Nations World Population Conference
Third	1980s-1990s	Global environmental change	Climate change Acid rain Ozone depletion	Report of the United States National Academy of Sciences Agenda 21 adopted by the United Nations Conference on Environment and Development Recommendations of the International Conference on Population
Fourth	1990s-present	Global environmental change	Biodiversity Genetic engineering Deforestation Water management Migration Emerging and re-emerging diseases Globalization	Programme of Action of the International Conference on Population and Development Resolution S-21/2 on key actions for the further implementation of the Programme of Action adopted by the General Assembly at its twenty-first special session

Source: Adapted from V. W. Ruttan "Population growth, environmental change and innovation: implications for sustainable growth in agriculture", in *Population and Land Use in Developing Countries*, C. L. Jolly and B. B. Torrey, eds. (Washington D.C., National Academy Press, 1993).

Figure VI

Estimates of how many people the Earth can support, by date of estimates



Source: Redrawn from Joel E. Cohen, *How Many People can the Earth Support?* (New York, W. W. Norton and Company, 1995), figure 11.1.

Note: Where a range of estimates was given by an author, it is the highest estimate that is shown here.

51. While the environmental problems discussed in this report are largely the result of human activities, they vary in the degree to which they can be linked directly to population size, growth or distribution. For example, increases in some types of pollution are primarily the by-product of rising per capita production and consumption in richer economies, where population has generally been growing slowly. Some types of pollution, such as the release of chlorofluorocarbons, which harm the planet's ozone layer, are linked to particular technologies much more than to either population change or overall economic growth. Even for those environmental problems that are concentrated in countries with rapid population growth, it is not necessarily the case that population increase is the main root cause, nor that halting population growth would resolve the problem, insofar as other social and technological "driving forces" are usually also contributing to environmental degradation.

52. Many of the environmental issues of greatest concern today involve resources that are to a greater or lesser degree "common property resources". "Common property resources are those valuable natural assets that cannot, or can only imperfectly, be reduced to private ownership. Examples are the air mantel, watercourses, complex ecological systems, large landscapes and the electromagnetic spectrum" (Kneese, 1977). Economic theory predicts, and much experiential evidence demonstrates, that unhindered access to such resources leads to overuse, misuse, and quality degradation. In the absence of effective social mechanisms to limit and ameliorate the tendency for common property resources to be overused and degraded, population growth will tend to exacerbate such problems. Population growth is rarely the only factor operating. Especially during recent decades, population growth has gone hand in hand with massive technological and social change.

53. Population growth is generally regarded as the single most important force driving increases in agricultural demand. Most recent expert assessments are cautiously optimistic about the ability of global food production to keep up with demand for the foreseeable future (that is to say, until approximately 2030 or 2050) (Alexandratos, 1999; Dyson, 1996; Mitchell and Ingco, 1995; Food and Agriculture Organization of the United Nations, 2000a). However, it is important to note that these assessments are predicated upon the expectation that population growth rates will continue to decline. At the same time, food insecurity, associated with poverty, is projected to persist for hundreds of millions of people. A host of environmental side effects derive from farming, and these pose serious threats to sustainability of food production in some areas. However, the Food and Agriculture Organization of the United Nations (FAO) has concluded that "with regard to poverty alleviation and food security, the inability to achieve environmentally sound and sustainable food production is primarily the result of human inaction and indifference rather than natural or social factors" (Food and Agriculture Organization of the United Nations, 1996a).

54. The need to feed a growing population is placing mounting stress on water supplies in many parts of the world. On a global basis, irrigation accounts for more than 70 per cent of fresh water taken from lakes, rivers and underground sources (United Nations, 1997b). While water is often inefficiently used, institutional mechanisms for implementing effective water management policies are often time-consuming, expensive and, in some cases, not viable options. Population pressures

are thus not the only, or necessarily even the primary, cause of ineffective water use and pollution, but they do aggravate the magnitude of ecological damage.

55. Population growth, through its effects on the expansion of cropland and the harvesting of wood for fuel, is also an important factor contributing to deforestation in some areas. Commercial logging is the predominant cause of deforestation in other areas.

56. Pollution of air and water is the principal environmental threat facing developed countries and a growing number of developing countries. High rates of emission of CO_2 and other greenhouse gases are also associated with high levels of development. In general, population growth appears to be much less important as a driving force of such problems than are economic growth and technology. Nevertheless, other things being equal, continued increase in population plays a role by increasing aggregate economic demand and hence the volume of pollution-causing production.

57. There is a special situation with respect to population when the issue is one of preserving a unique, biologically rich, or fragile ecosystem. Such preservation is inherently incompatible with dense human settlement or heavy exploitation of the resources of the protected area. Population growth within and near the preserve can be a factor, among others, placing such areas at risk of degradation. Government regulation is generally needed to exclude or at least limit the number of settlers, animal herders, logging operations and other uses incompatible with preservation of the natural ecosystem. However, few such areas are completely uninhabited. Some are the home of indigenous people, and sometimes established farming communities nearby have traditionally had rights to harvest forest resources. These populations are often very poor and depend on the protected resources for their livelihood. Often it is the women in such communities whose harvesting rights are principally at stake. Increasingly, both Governments and non-governmental organizations concerned with conservation have recognized the need to consider the needs of the local people when implementing preservation programmes. There have been some successes in such programmes, but they are far from universal. Many Governments of developing countries have had great difficulty in providing effective protection to areas designated for preservation. Wars, civil strife, ineffective administrative systems and corruption must be numbered among the greatest threats to protection of such areas.

58. In considering responses to environmental problems, it is important to recognize that social-institutional factors can be equally as important as, if not more important than, technological ones. The general problem of managing locally scarce or fragile resources is not new. Many examples can be found where traditional societies developed communal rules for managing a scarce resource. Such rules, where successful (and examples of failures can also be found), must solve both the problem of how to maintain the resource and the social problem of ensuring equitable access among society's members. Population growth has the potential to destabilize such communal arrangements, since rules that functioned adequately at a low population density may lead to overexploitation and/or pollution at a higher density. Successful adaptation may be possible — as, for instance, in the transition described by Ester Boserup (1965) from shifting to settled agriculture — but it is important to note that changes in the social allocation of resources are likely to be required as part of such adaptation. Even though the overall social as well as

environmental benefit to such organizational change may be large, the process is likely to be contentious and politically difficult. Indeed, there are apt to be losers as well as winners in any such process; achieving an equitable transition represents a major social and political challenge at all levels, ranging from local to national — and even international, when we consider problems that have a global impact, such as emissions of greenhouse gases.

59. In summary, population growth is a contributing factor to many types of environmental stress. The role of increasing population size is especially prominent as the major force driving the need to increase food production, and the environmental stresses on water, forests, soil and air that stem from agriculture. However, as concluded in the 1990s by an in-depth scientific inquiry, population growth "is not the only factor affecting the rate of resource degradation, and in many contexts it is undoubtedly not the most important factor ... (There is) a huge array of obstacles to expanded food production and better resource management. These include weak land tenure systems, inadequate credit availability, biased agricultural prices and exchange rates, adverse tax policies, weak agricultural extension services, excessive government control, and civil wars. But few if any of these problems will be resolved through rapid population growth. They are the context on which this growth will be imposed" (Preston, 1994, p. 9).

60. Even for those environmental issues for which population change appears to be a relatively minor factor by comparison with recent trends in per capita consumption or in pollution-causing technologies, over the longer term the effect of alternative paths of population growth will assume more importance. "The widely recognized momentum of population growth cuts both ways. While it reduces the apparent advantages of lower fertility in the short run, it may increase them in the long run. The fact that population growth is a ponderous process means that whatever happens today has multiplier effects in each successive generation. In a very real sense, today's births are tomorrow's momentum. The more concerned we are with long-term futures, the more important are population policies in the array of strategies for enhancing the human condition" (Preston, 1994).

IV. Migration, population change and the rural environment

61. Population change, particularly via migration, has had an important impact on the rural environment, on both forests and dryland areas. Most of the world's gene pool is concentrated in such rural environments, especially the tropical rainforests, which are threatened by the growth and intrusion of human populations. Despite two centuries of rapid urbanization, the majority of the world's population still lives in rural areas, and for at least two more decades most people in the developing world will continue to be rural inhabitants. It is therefore important to consider the interrelations among rural population growth, migration and the rural environment, particularly with respect to the changes experienced by developing countries since 1950.

62. The twentieth century has witnessed a profound shift of the world population from rural to urban areas (United Nations, 2000d). Thus, the proportion of the population living in rural areas declined from 66 per cent in 1960 to 53 per cent in 2000. Because urbanization began earlier in the more developed regions and in Latin America, by 2000 only a quarter of their population lived in rural areas, in contrast

to two thirds of the population of Africa or Asia. Despite the reduction in the percentage of people residing in rural areas, there has been a large increase of the absolute number of persons residing in the rural areas, from 2 billion in 1960 to 3.2 billion in 2000 (table 3). That increase has been concentrated entirely in the less developed regions. Particularly large gains occurred in Asia, whose rural population rose from 1.3 billion in 1960 to 2.3 billion in 2000, and in Africa where the rise was from 225 million to 487 million. Over the next 30 years, virtually no growth is expected in the rural population of the world, and even that of the less developed regions will increase by less than 100 million, mostly in Africa.

63. Rural population growth since 1960 has been particularly rapid in Africa and in Melanesia and Micronesia, at nearly 2 per cent per year. Although slower rural growth is expected during 2000-2030 in all regions, 10 of the 21 regions in the world are still expected to see their rural population increase, with substantial rises likely in Eastern Africa, Middle Africa, Western Africa, Melanesia and Micronesia. Many of the countries in those regions already have seriously degraded rural environments and difficulties in feeding their populations (Food and Agriculture Organization of the United Nations, 1996b; Cleaver and Screiber, 1994; Higgins and others, 1982). In South-central Asia and Western Asia, rural population growth is expected to be modest but countries in those regions already have high rural population densities. Lastly, Central America is the only part of Latin America in which an increase of the rural population is expected.

64. Most of the rural population of the world is concentrated in a few countries, with just 34 countries accounting for 85 per cent of the world's rural population and 3 having more than 100 million rural inhabitants each (China, India and Indonesia). By 2030, Bangladesh and Pakistan will also pass that threshold. However, less populous countries, such as Uganda and Yemen, are expected to have the highest rates of future rural population growth, at over 2 per cent per year. Rural growth will likely also exceed 1.5 per cent per year in Afghanistan, the Democratic Republic of the Congo, and Ethiopia. Countries that experience high rates of rural population growth are more likely to face problems of environmental degradation in rural areas. In past decades, rural population density more than doubled in the Democratic Republic of the Congo, Ethiopia, Kenya and Yemen, while it rose by over 70 per cent in Bangladesh, India, Myanmar, Nigeria, Pakistan and Viet Nam.

Table 3
Rural population and rural growth rate by major area and region, 1960-2030

Major area or region	*Rural population (millions)*			*Rural rate of growth (average annual percentage)*	
	1960	*2000*	*2030*	*1960-2000*	*2000-2030*
World	2 005.2	3 210.0	3 222.6	1.18	0.01
More developed regions	353.3	285.0	199.7	-0.54	-1.19
Less developed regions	1 651.9	2 925.0	3 022.9	1.43	0.11
Africa	225.4	487.3	640.2	1.93	0.91
Eastern Africa	76.4	182.4	259.9	2.18	1.18
Middle Africa	26.1	61.8	96.1	2.15	1.47
Northern Africa	46.8	85.3	88.6	1.50	0.13
Southern Africa	11.4	24.3	22.1	1.89	-0.31
Western Africa	64.6	133.5	173.6	1.81	0.88
Asia	1 348.4	2 330.7	2 271.8	1.37	-0.09
Eastern Asia	613.0	913.5	776.3	1.00	-0.54
South-central Asia	507.6	1 035.3	1 116.7	1.78	0.25
South-eastern Asia	185.0	325.9	313.4	1.42	-0.13
Western Asia	42.8	56.1	65.5	0.67	0.52
Europe	254.0	184.0	120.4	-0.81	-1.42
Eastern Europe	132.1	88.4	55.9	-1.00	-1.52
Northern Europe	20.1	15.3	11.1	-0.68	-1.08
Southern Europe	59.7	48.4	31.2	-0.52	-1.47
Western Europe	42.2	32.0	22.2	-0.69	-1.22
Latin America and the Caribbean	110.7	128.3	121.5	0.37	-0.18
Caribbean	12.2	14.1	13.0	0.37	-0.28
Central America	26.3	44.3	47.5	1.30	0.23
South America	72.2	69.9	61.0	-0.08	-0.45
Northern America	61.4	70.6	58.1	0.35	-0.65
Oceania	5.3	9.1	10.5	1.35	0.51
Australia/New Zealand	2.6	3.4	3.2	0.74	-0.20
Melanesia	2.4	4.9	6.4	1.86	0.89
Micronesia	0.1	0.3	0.4	1.98	1.06
Polynesia	0.2	0.4	0.4	1.25	0.57

Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, "World urbanization prospects: the 1999 revision: data tables and highlights" (ESA/P/WP.161), March 2000.

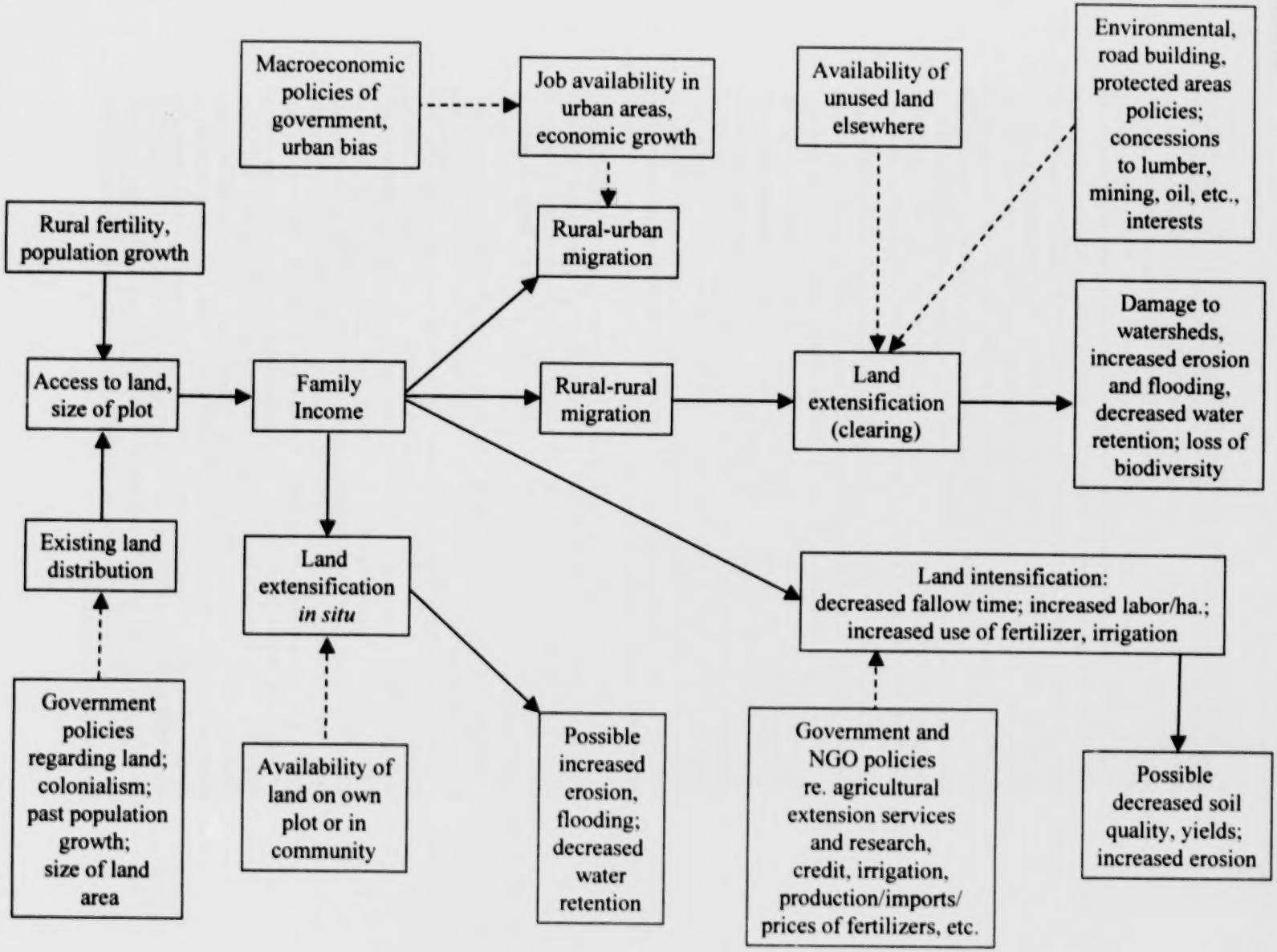
65. In the future, at least two mutually countervailing forces will continue to lead to changes in arable land: the absorption of agricultural land by expanding urban areas and the extension of agricultural land through the colonization of the agricultural frontier. Both involve the redistribution of population over a country's territory, usually via migration. Rural-urban migration is a major component of urban growth, and has dominated the literature and policy discussions. However, in countries where most of the population lives in rural areas, rural-rural migration is more common. Thus for 11 of the 14 countries with data on the different types of migration flows (a set that includes some of the most populous countries, such as Brazil, India and Pakistan), rural-rural migration was larger than rural-urban migration during the 1980s and often before. This should be borne in mind when the role of rural-rural migration as the process through which population interacts with the rural environment is considered, since it is through out-migration that a population may respond to a deteriorating rural environment and via in-migration that human populations may exert pressure on fragile rural environments.

66. In the analysis of the possible impacts of population on the rural environment, various measures of environmental degradation may be considered. The focus here is mostly on deforestation, the most studied impact because deforestation is associated with a significant loss of biodiversity, soil erosion and global warming. On a global scale, 60 per cent of recent deforestation in the developing world may be attributable to the advance of the agricultural frontier, 20 per cent to logging operations (including mining and petroleum) and 20 per cent to household use of fuelwood (World Bank, 1991). While the importance of these factors varies across regions and countries, demographic factors are thought to play significant roles in both the advance of the agricultural frontier and fuelwood use (Food and Agriculture Organization of the United Nations, 2000c).

67. Analysing the linkages among population, migration and the rural environment is complex because population pressure and environmental deterioration may both induce out-migration from areas of origin and be consequences thereof in areas of destination (see figure VII). Ever since the first hunter-gatherers depleted game in their immediate vicinity, humans have resorted to migration as a mechanism for reconciling human wants to resources. The factors that propel people to leave their place of origin may be referred to as "push" factors and include both natural disasters and gradual environmental degradation resulting from human activity, such as floods caused by the deforestation of watersheds or soil degradation due to improper land-use practices. Both sudden natural disasters and gradual human-induced environmental degradation in rural areas reduce the productivity of resources and therefore the incomes of those dependent on them, and hence may induce out-migration. However, empirical evidence on the effect of environmental factors on out-migration is virtually non-existent owing to the lack of data distinguishing environmental factors from other economic factors that may induce migration. Still, there is a growing interest in environmentally induced migration, especially among so-called environmental refugees, that is to say, international migrants compelled by environmental conditions to seek temporary asylum in another (usually neighbouring) country, and among "displaced persons", that is to say, people forced by environmental disasters to migrate within their own country. However, the precise role of environmental factors in such movements has been hard to establish because political, civil, religious or ethnic conflicts have also been involved in their generation.

Figure VII

Linkages among rural population growth, migration and the rural environment


Macroeconomic policies of government, urban bias
Job availability in urban areas, economic growth
Availability of unused land elsewhere
Environmental, road building, protected areas policies; concessions to lumber, mining, oil, etc., interests
Rural fertility, population growth
Rural-urban migration
Access to land, size of plot
Family Income
Rural-rural migration
Land extensification (clearing)
Damage to watersheds, increased erosion and flooding, decreased water retention; loss of biodiversity
Existing land distribution
Land extensification *in situ*
Land intensification: decreased fallow time; increased labor/ha.; increased use of fertilizer, irrigation
Government policies regarding land; colonialism; past population growth; size of land area
Availability of land on own plot or in community
Possible increased erosion, flooding; decreased water retention
Government and NGO policies re. agricultural extension services and research, credit, irrigation, production/imports/ prices of fertilizers, etc.
Possible decreased soil quality, yields; increased erosion

68. In developed countries, environmental deterioration has often led to out-migration from rural areas. Sometimes environmental changes have been due to natural causes, while at other times they have been induced by human practices. An example of the former is the effect of climate change (less precipitation) on agriculture and therefore in stimulating out-migration from the Great Plains of the United States during the "dust bowl" era of the 1930s (Gutmann and others, 1996). Apart from the effects of nuclear and industrial accidents, toxic and solid waste dumps, and severe air or water pollution, human practices have often led to gradual but severe deterioration of rural environments. A striking example is the shrinkage by half of the large, inland Aral Sea in the Russian Federation due to excessive withdrawal of water for the irrigation of cotton fields, a shrinkage that has produced out-migration from the area (Postel, 1996).

69. Since in-migration increases the population density of areas of destination, it may affect the environment. The extent to which land is cleared in areas of destination depends upon population density, as suggested by the theories of Malthus, Boserup and others. An important question is whether the poor are especially involved in causing environmental damage. It is true that the poor tend to live on "low potential", marginal lands, and that those lands are more likely to become degraded when used (Barbier, 1997), forcing the poor to migrate to other marginal areas where the degradation process begins again. It is through this process that poor migrants contribute to deforestation, although the underlying causes of that outcome include their lack of access to adequate land in the place of origin. However, in terms of total area of land being cleared in the developing world, especially in Latin America, most deforestation is caused by large landholders and agro-business when clearing the land for pasture in response to global consumption demands.

70. The body of research on the impacts of migration on the rural environment in developing countries has focused on migrant colonists and their impact on the rainforest frontier. Such migrants have been the direct agents of a significant proportion of the tropical deforestation. Thus Brazil, with 35 per cent of the world's rainforests, has lost the largest absolute volume of tropical forests in recent decades owing to the extension of the agricultural frontier, following the construction of two highways (BR-364 to Rondônia and the Transamazon Highway). In the context of high rates of population and industrial growth, national policy promoted a westward expansion to tap the wealth of the Amazon and provide a release valve for peasants who had insufficient land elsewhere (especially in the drought-stricken north-east). High fertility in the north-east contributed to growing population pressures on the land and to rural poverty, which helped to fuel out-migration once the Amazon region was made accessible.

71. Migration to the rainforest frontier followed by large-scale forest-clearing has also been documented in other countries, including Guatemala, Panama, Costa Rica, Ecuador, Mexico, Indonesia, Thailand, Nepal, the Philippines, Nigeria, the United Republic of Tanzania and the Sudan. In Guatemala, for example, migration into the northern Petén resulted in the clearing of half the forests in the region during 1950-1985. As in Brazil, high population growth in areas of origin (the Guatemalan Altiplano), characterized by extreme inequality in landholdings, led to an increasing fragmentation of plots over time as they were subdivided among children and contributed to rising rural poverty, which together with lack of access to land, stimulated out-migration from rural areas to both Guatemala City and the Petén

(Bilsborrow and Stupp, 1997; Sader and others, 1997). In southern Honduras, government policies played an important role, promoting cattle ranching and plantations of cotton and sugar cane to increase exports, which facilitated the taking over of good lowland areas by large, commercial landowners. These developments forced smallholders to migrate to nearby mountain slopes to establish new farms. The clearing of slopes led to soil erosion and flooding downstream, exacerbating rural poverty. In Ecuador, migration eastward to the Amazon and the massive deforestation that ensued began in the early 1970s with the construction of roads by petroleum companies to lay oil pipelines. Those roads facilitated a large influx of migrant colonists, three fourths from rural areas of the highlands (Pichón, 1997; Pichón and Bilsborrow, 1999). A longitudinal survey of migrant settler households conducted in 1990 and 1999 found that many of the original plots in the Amazon region had been subdivided and the population of colonists was doubling nearly every nine years, increasing the proportion of the original plot that had been deforested from 46 to 57 per cent (Pan and Bilsborrow, 2000; Murphy, 2000).

72. Similar findings exist for other continents. Thus Indonesia, the world's fourth most populous country and third in terms of tropical forest stock, has been experiencing the second highest annual volume of forest loss, some of which has been caused by migrant colonists (Food and Agriculture Organization of the United Nations, 1997). Both the Government-sponsored Transmigration Programme, aimed at reducing high population density in Java and Bali, and the spontaneous movement of migrants have led to increased population density in forested areas and caused deforestation. In Thailand, substantial deforestation occurred in the north at the hands of migrant colonists (Panayotou and Sungsuwan, 1994); and in the southern hill region of Nepal, migrant colonists settled after a successful dichlorodiphenyl trichloroethane (DDT) campaign to reduce malaria, leading to the clearing of forests (Shrestha, 1990). In the Philippines, a process occurred similar to that in Honduras, with the lowlands coming increasingly under the control of large landholdings devoted to cash crops, such as sugar cane and cattle grazing, so that the growing rural population could find new land only on the increasingly steep adjoining mountain slopes; but once the forests were cleared to establish agricultural plots, erosion and flooding increased (Cruz, 1997). The rising frequency of floods in Bangladesh is also attributed to extensive forest-clearing in the watersheds of India and Nepal.

73. Rural-rural migration is also prominent in migration-environment linkages in Africa. In the United Republic of Tanzania, the spread of cash crops (especially coffee and cotton) was stimulated by government policy and led to substantial rural-rural migration to the Usangu plains, depleting their vegetation. The human population of the plains rose fivefold between 1948 and 1988 and the number of cattle doubled. However, the ecological deterioration was also partly due to insecure land tenure and the absence of social institutions for regulating resource access and use (Charnley, 1997). In Nigeria, the Koyfar of the Jos plateau, responding to expanding market opportunities rather than population pressure, migrated from the fertile Benue plains and changed from being shifting cultivators in temporarily cleared areas of forest to being permanent and intensive tillers of family farms in areas cleared of forest.

74. Deforestation can also be caused by populations seeking fuelwood to meet energy needs, especially the poor and certain migrant groups, such as displaced persons and refugees. In Africa, Central America and Asia, large populations of

displaced persons or refugees have had to live in makeshift camps for long periods. Deforestation has resulted from the use of nearby forests for fuelwood, and the depletion of surface and underground water has also occurred (Sessay and Mohamed, 1997).

75. Population growth and in-migration have also been linked to vegetation loss in dryland areas, especially in sub-Saharan Africa. Thus numbers of pastoralists and the animal herds they depend on have both increased substantially in recent decades, leading to increased migration in search of additional grazing lands and increasing competition for land with sedentary populations.

76. While the case studies indicate that migration to marginal or fragile areas usually results in environmental degradation, factors other than migration are often the main precipitating factors, including the actions of Governments, national and multinational corporations (logging and mining enterprises) and large-scale ranchers responding to national and international demand for wood, beef and other agricultural products. Roads and infrastructure have frequently facilitated the arrival of migrants.

77. At the same time, out-migration may relieve environmental pressures in areas of origin. In the Camacho Valley of Bolivia, for instance, out-migration resulted in less intensive grazing and improvement of the environment (Preston, 1998). However, in the Peruvian Andes and in an island in Lake Victoria, out-migration led to a depletion of the labour supply that made it hard to maintain terraces, and resulted in increased soil erosion (Collins, 1986). In developed countries, the agricultural frontier has long been closed. Rural populations are declining throughout the developed world, while the area in secondary forest has been stable or rising. In the last half of the twentieth century, out-migration from rural areas has almost invariably been to urban destinations rather than to forest frontiers as in tropical developing countries.

78. A review of recent literature on population growth, migration and the rural environment has provided numerous examples in which the migration of farmers to the agricultural frontier has resulted in tropical deforestation or the desiccation of land in dryland areas. These examples also indicate the crucial role of natural resource endowments, institutions, local and national policy and, in some cases, international markets and cultural factors. Given that many of the areas being settled are characterized by extraordinary biodiversity and that tropical forests also play crucial roles in world climate patterns and in preventing global warming, it is important to address the root causes of the migration that leads to deforestation. Since most of the migrants involved are poor, a major challenge is to find ways of combating rural poverty while promoting a more sustainable use of the rural environment in areas of origin.

V. Health, mortality, fertility and the environment

79. Health concerns underlie much of the recent discussion about the consequences of environmental degradation. Environmental threats to health have been classified into two categories: "modern hazards", which are associated with development that occurs without adequate environment-health safeguards; and "traditional hazards", which are generally associated with the lack of development (World Health Organization, 1997). Modern environmental hazards include water

pollution from populated areas, urban air pollution, poor control of solid and hazardous waste materials, chemical and radiation hazards, deforestation and other problems related to ecological and climate change and stratospheric ozone depletion. Emerging and re-emerging infectious diseases have also been classified as modern environmental hazards (ibid.) because of their close association with outcomes of economic development. Traditional environmental health hazards include poor control of disease vectors, poor sanitation, contamination of food and drinking water, indoor and outdoor air pollution from fires and particulate matter, poor waste disposal and natural disasters.

Modern environmental health threats

80. Evidence on the health effects of specific modern environmental health threats is scattered and often supported largely by data from experimental situations that do not adequately represent the levels of exposure in actual populations. However, there is considerable evidence to suggest that whether they are present in air, water or food, a host of chemicals and gases that are released into the environment as a result of agricultural or industrial processes can have negative effects on health. In addition, exposure to ionizing radiation from nuclear power stations or from natural sources has been associated with negative health consequences (Corvalán and Kjellström, 1995).

81. A major health threat in both developed and developing countries arises from air pollution, especially by suspended particulate matter (SPM), which is estimated to account for about 3 million deaths globally each year (World Health Organization, 1997). SPM consists of a mixture of fine and coarse particles that are generated from combustion and mechanical processes. The smallest molecules of SPM — typically found in smoke from diesel engines, burning, cigarette smoke and some types of industrial activity — are the most dangerous to health because they can reach deep into the respiratory system (De Souza, 1999). It should be noted that although particulate pollution in developed countries is largely a result of modern environmental pollutants, traditional sources such as smoke from indoor fires contribute a large share of the SPM in developing countries. Lead is a common constituent of SPM. Considerable evidence links exposure to lead to reduced intelligence, impaired mental development, reduced birth weight and disturbances of the nervous system (Pocock, Smith and Baghurst, 1994; World Health Organization, 1997). The inhalation of fumes from the combustion of leaded gasoline remains an important source of low-level persistent exposure in developing countries where leaded gasoline is still in use.

82. Many of the pollutants that occur in the air are also present in water and food sources. The application of fertilizers and pesticides in agriculture is a primary source of pollution of groundwater and food. Dietary intake of cadmium, lead, mercury, polychlorinated biphenyls (PCBs), and pesticides has been found to exceed acceptable daily intakes in a number of developed countries, with consumption by infants and children being particularly in excess of these acceptable limits (Baht and Moy, 1997). Arsenic in drinking water is also a continuing global health threat because it can cause neuropathy, cardiovascular disease, and skin and internal cancers including those of the liver, lung, kidney and bladder. A strong association between high nitrate ingestion and recurrent respiratory tract infection has been reported (Gupta and others, 2000). Because many chemicals also cross the placental

barrier, there are health risks to the unborn child when pregnant women consume contaminated food and water.

83. Modern environmental pollutants are also believed to have negative effects on human fecundity and reproductive health although the evidence remains controversial. Chemicals thought to play a major role in this relationship include naturally occurring steroid and synthetic hormones, organic and inorganic pesticides, PCBs and dioxins (Swan and others, 1997). Exposure to PCBs has, for example, been found to account for poorer neonatal and early childhood health (Swain, 1991), impairment of fertility, irreversible growth retardation and subtle behaviour change in newborns (Gilbertson and others, 2000). Chemical agents that have been used to enhance ovulation have also been linked to negative reproductive health consequences such as reduced viability of pregnancy, a higher incidence of spontaneous abortions, and increased risks of breast, ovarian and uterine cancer (Tucker 1996; Venn and others, 1999). It should be noted that even if environmental factors have had a negative effect on fecundity, there is little evidence that overall levels of fertility have been affected. In Belarus and Ukraine where studies have shown that the period immediately following the Chernobyl nuclear accident was characterized by a sharp drop in fertility, it appears that factors other than impairment of fecundity played an important role. In particular, the emigration of women of reproductive age, especially those who were pregnant, increases in the number of abortions, and delayed fertility for fear of the side effects of the Chernobyl disaster played important roles in the fertility decline (Rybakovsky, 1994).

Traditional environmental health threats

84. As a result of major improvements in sanitation, community water supply, housing and indoor air quality, most of the diseases associated with traditional environmental factors are no longer of major significance in more developed regions. In less developed regions of the world, however, diseases that are associated with poor sanitation, faecal contamination of water and food, contaminated indoor and outdoor air, and infections via insect or animal vectors continue to cause significant mortality and morbidity. Deaths due to diseases associated with poor water supply, sanitation and personal and domestic hygiene alone are estimated to have accounted for 5 per cent of global deaths and 9 per cent of all premature deaths in 1990 (Murray and Lopez, 1996). Worldwide, almost one in five deaths is caused by infectious and parasitic diseases. The major contributors to mortality are diarrhoeal diseases, which are transmitted primarily through faecal contamination of food and water, and the childhood cluster diseases such as pertussis, poliomyelitis, diphtheria, measles and tetanus, which are more easily spread under crowded and unhygienic living conditions.

85. Diseases associated with traditional environmental factors also account for considerable disability. Infectious diseases, as a group, account for about one quarter of disability in the world, with less developed regions bearing the heaviest burden. Furthermore, tropical diseases such as trypanosomiasis, Chagas' disease, schistosomiasis, leishmaniasis, lymphatic filariasis and onchocerciasis all account for low levels of mortality worldwide, but for a high level of disability, principally in India and sub-Saharan Africa (Murray and Lopez, 1996).

86. The level of mortality and disability associated with traditional environmental health hazards is often much higher than that directly attributed to the diseases they cause. Many food-borne diseases, for example, can lead to serious and chronic sequelae and affect the cardiovascular, renal, respiratory or immune system. Food-borne infections are also one of the most important underlying factors in malnutrition, in rheumatic disease and, indirectly, in respiratory tuberculosis (Bunning and others, 1997; Käferstein, 1997). There is evidence that the immune system can be negatively affected by exposure to biological pathogens in the environment. *Helicobacter pylori* (*H. pylori*), for example, is a water-borne infection that has been linked to the development of gastric ulcer and gastric cancer (Hosking and others, 1994; Hansson and others, 1996; Parsonnet, 1996). The improvement of the water supply and the reduction in exposure to *H. pylori* are believed to have accounted for marked reduction in deaths due to gastric cancer in the United States since the 1930s (Manton, Stallard and Corder, 1999).

New and re-emerging diseases

87. Environmental factors play an important role in the emergence and gravity of a number of new diseases of the twentieth century. These include human immunodeficiency virus (HIV) infection, Ebola and other zoonotic diseases, and drug-resistant strains of previously known pathogens. Rapid population growth and associated greater incursions into the natural land and water habitats have fostered the growth and spread of pathogens previously confined to certain domains. By far the most important of these diseases is HIV/AIDS, which is estimated to have killed more than 18 million people since the epidemic began (Joint United Nations Programme on Human Immunodeficiency Virus/Acquired Immunodeficiency Syndrome (UNAIDS), 2000). HIV, which causes acquired immunodeficiency syndrome (AIDS), is transmitted mainly through sexual contact and injecting drug use; but once an individual is infected, the progression from HIV infection to full-blown AIDS is faster when opportunistic infections are present (Muller and others, 1999; Cohen and Miller, 1998). Environmental factors influence the transmission of a number of the most common opportunistic infections (OIs). Exposure of HIV patients to unsanitary environments and to animals, poultry, raw meat, soil and contaminated fruits and vegetables increases their risks of contracting toxoplasmic encephalitis, histoplasmosis, cryptosporidiosis and cytomegalovirus and adenovirus infections (Centers for Disease Control, 1997, 1999; Hierholzer, 1992). Tuberculosis remains the primary opportunistic infection in HIV/AIDS patients in developing countries, especially in sub-Saharan Africa where the epidemic is most severe. One half of HIV cases in developing countries are complicated by tuberculosis (Joint United Nations Programme on Human Immunodeficiency Virus/Acquired Immunodeficiency Syndrome (UNAIDS), 2000) and this may reflect the prevalence of crowding in households and communities and the overall higher prevalence of tuberculosis in these contexts.

Factors associated with morbidity and mortality from environmental causes

88. Both modern and traditional environmental health threats appear to have their largest impact on the young, especially those under age 5. Adolescence is also a period of high risk because of the maturation of a number of organs, including those

in the reproductive, respiratory, skeletal, immune and central nervous systems, which are subject to the toxic effects of environmental chemicals (Golub, 2000). Various studies have shown that infants and young children are up to 10 times more sensitive than adults to the effects of radiation and that there is no threshold level below which exposure of the thyroid to radiation is not risky (Braverstock, 1993). Children under age 5 suffer the highest mortality and bear the heaviest burden of diseases caused by poor sanitation, crowded living quarters and contamination of food and water. Seventy per cent of deaths from acute respiratory infections, most of which are related to environmental factors, occur before the first birthday and one quarter of the deaths among children under age 5 are estimated to be due to diarrhoea (World Health Organization, 1995).

89. Women and young girls, because of their traditional role in the preparation of food, are also at high risk of exposure to particulates from the smoke emitted from the burning of coal, fuelwood, animal dung and other sources of fuel (World Health Organization, 1997). Lifestyle factors, especially whether an individual is a smoker or is exposed to environmental tobacco smoke, also appear to modify the health consequence of chemical pollutants. Nicotine and tar inhaled from smoking appear to interact synergistically with other chemical exposures, to produce a large negative effect on health (Kjellstrom and Rosenstock, 1990).

90. Climatic factors in tropical regions of the world also provide ideal conditions for the survival and proliferation of disease pathogens. Increases in the prevalence of various diseases, including dengue, malaria and other mosquito-borne arboviruses, have been associated with climate and rainfall (Loevinsohn, 1994; Watts and others, 1989). Although diet undoubtedly plays an overarching role, there are suggestions that recent increases in the global incidence of insulin-dependent diabetes may be related to environmental factors, possibly climate (Leslie and Elliott, 1994). The disease shows a strong south-north gradient in incidence, with rates increasing with latitude (Rewers and others, 1988). Socio-economic factors are also important mediators of the environment-health link. Education, income and occupation determine the extent to which individuals can modify or control environmental threats to health. It is estimated that trachoma, in its active inflammatory form, affects about 46 million people worldwide, but mainly those who live in poverty and under conditions of crowding and insufficient personal and environmental hygiene (Thylefors, 1999).

91. High fertility and rural-urban migration have led to rapid growth in many countries. This urban growth has often outpaced the provision of safe water and sanitation. In addition, increasing urban population size and associated economic activity add to the volume of liquid and solid wastes released into the environment. Crowded living conditions also facilitate the spread of diseases such as tuberculosis and measles (World Health Organization, 1997).

92. Both affluence and poverty continue to play important roles in the persistence of environmental health threats. On the one hand, affluence, leading to increasing demand for more and better consumer goods and services, results in intensification of production in ways that have led to pollution from various chemicals that are inputs or outputs in the production process. In developing countries, poverty in conjunction with high population growth has led to sustained pressures on natural resources, to urbanization, to the growth of urban slums and to increased opportunities for disease transmission.

VI. Population, environment and development in urban settings

93. Urbanization will be one of the most important demographic trends of the twenty-first century. Indeed, virtually all the population growth expected during 2000-2030 will be concentrated in the urban areas of the world (United Nations, 2000c). Growth will be particularly rapid in the urban areas of the less developed regions, averaging 2.3 per cent per annum during 2000-2030, consistent with a doubling time of 30 years. Although urban areas will encompass an increasing share of the world population, the proportion of people living in very large urban agglomerations is still small (in 2000, only 4.3 per cent of the world population lived in cities of 10 million inhabitants or more). In contrast, the proportion of the world population living in small cities is considerably larger (in 2000, 28.5 per cent of the world population is estimated to have been living in cities of less than 1 million inhabitants) (United Nations, 2000c).

94. Population growth influences the spatial concentration of people, industry, commerce, vehicles, energy consumption, water use, waste generation, and other environmental stresses (Bartone, Bernstein and Leitmann, 1992). It is often assumed that cities' environmental problems are made worse by the number of people and their high concentration; but in fact this same concentration provides many potential opportunities. The concentration of population and enterprises in urban areas greatly reduces the unit costs of providing each building with piped water, sewers, drains, roads and electricity. Moreover, cities concentrate populations in ways that usually reduce the demand for land relative to population. Although valuable land is being lost to urban expansion, in most nations the area taken up by cities and towns is less than 1 per cent of their total surface area. Indeed, the world's current urban population of about 3 billion inhabitants would fit into an area of 200,000 square kilometres — roughly the size of Senegal or Oman — at densities similar to those of inner city residential areas in a number of European cities (Hardoy, Mitlin and Satterthwaite, 2000).

The relationship between city size, rate of growth and urban environmental problems

95. The relationships between city size, or city size distributions on the one hand, and environmental damages on the other hand, are numerous, complex and very poorly understood (Prud'homme, 1994). The environmental impact of city size is generally considered negative. The larger the city, it is assumed, the greater the per capita environmental costs or damages. However, a number of caveats are in order. Since what ultimately counts is not so much pollution discharged, but rather pollution discharged minus pollution eliminated, it is important to note that, for a number of pollutants (for example, solid waste, water pollution), there are economies of scale in pollution abatement. Also, large cities are generally resource-saving relative to smaller cities; they are usually denser; and they lend themselves better to public transportation usage and include a larger share of apartment buildings, hence they consume less land and less energy per capita. Finally, because transportation flows increase with population dispersion, environmental impacts associated with transportation (for example, fossil fuel consumption, greenhouse gas emissions, air pollution) presumably could be reduced by increased concentration in a few large cities.

96. Given that, in most countries, a significant proportion of urban-dwellers live in relatively small urban centres, there is a remarkable lack of documentation on environmental problems other than those in the largest cities. The limited information available about provision of water, sanitation and garbage collection in smaller cities suggests that most have serious environmental problems (Hardoy, Mitlin and Satterthwaite, 2000). This is perhaps not surprising, given that larger cities are typically more prosperous and obtain more government resources and attention. In most smaller African urban centres, for example, local authorities lack the capacity to ensure adequate provision of water, sanitation and garbage collection. In Asia, there is far more documentation of the environmental problems in large cities — partly because census data about the quality of housing and of provision of water, sanitation and drainage are rarely made available for individual urban centres. However, a number of independent research studies provide examples of serious deficits in urban infrastructure and services in smaller cities in India (see, for example, Ghosh, Ahmad and Maitra, 1994). Likewise, there are also case studies of a number of smaller cities in Latin America showing the inadequacies in provision of water, sanitation and drainage (see Foronda, 1998; Browder and Godfrey, 1997). One such case study — of "boom cities" on the Brazilian agricultural-forest frontier — illustrates the fact that environmental problems are likely to be particularly serious in cities that grow very rapidly in newly settled areas, since it is rare for there to be any government institution able to manage the rapid growth and ensure adequate provision for environmental health (Browder and Godfrey, 1997).

97. In general, however, there is not necessarily a strong direct linkage between the rate of urban growth and environmental problems. Over the past several decades, the growth rates of many of the world's largest cities have slowed considerably (United Nations, 2000c). Yet a variety of urban environmental problems have worsened in many of these cities. Conversely, rapid urban change need not produce serious environmental problems. Cities such as Curitiba and Pôrto Alegre in Brazil have been among the world's most rapidly growing cities in recent decades, yet each has much fewer serious environmental problems than virtually all cities in developing countries that have grown far more slowly (Hardoy, Mitlin and Satterthwaite, 2000).

The city environment

98. The relationships between urbanization and environmental degradation are very complex, involving interactions with the natural and the built environment, as well as a variety of economic, social and political factors. The regional ecosystem in which a city is located, for example, is often a critical determinant of the severity of environmental conditions, as well as the complexity of potential intervention strategies. The wide variety in ecosystem types (for example, coastal regions, arid regions, humid-tropical regions, cold regions, mountainous regions) and the number of combinations make it difficult to devise a simple typology applicable to all environmental problems encountered in the world's large cities (Bartone, Bernstein and Leitmann, 1992). In the case of ambient pollution, for example, the vulnerability of large cities to the adverse impacts of vehicle emissions depends on certain natural features (for example, altitude, direction and speed of prevailing winds; amount of sunlight; atmospheric stability; precipitation and humidity). The case of Santiago

offers a striking example. Although emissions in Santiago are only 10 per cent of those in São Paulo, because of its climate and altitude, the magnitude and severity of air pollution episodes in Santiago are similar to those in the much larger city of São Paulo (Faiz, 1992).

99. Even if the less developed regions have a smaller proportion of their population living in cities (although this is no longer true for Latin America) and are relatively less industrialized, industrial production in many developing countries has often increased very rapidly in the absence of an effective planning and regulation system. The more rapid the growth in industrial production, the more serious the environmental problems related to industrial pollution are likely to be, since time is required to identify and act on problems, develop the legislative basis for pollution control and develop the institutional structure needed to implement it (Hardoy, Mitlin and Satterthwaite, 2000). However, industrial pollution is not the only cause of water and air pollution. The high proportions of households and businesses not served by sewers, drains and solid waste collection add greatly to water pollution problems in cities in the developing world. Moreover, the often rapidly growing numbers of motor vehicles, congested roads and a high proportion of inefficient and poorly maintained motor vehicle engines add greatly to air pollution.

Environmental impacts on urban health

100. Compared with the complex linkages among the environment, city size and rates of urban growth, the linkages between environmental degradation and health are more straightforward. Again, as in the case of aggregate levels of air and water pollution, there is much impressionistic evidence, but few comprehensive studies, using comparable data. Water is an important vehicle for the transmission of many pathogenic micro-organisms as well as organic and inorganic toxic substances. Many of the more important transmissible diseases in the developing countries can be classified according to the role played by water in the chain of transmission: water-borne diseases (for example, enteric and diarrhoeal disease, typhoid fever, hepatitis); water hygiene diseases (for example, trachoma, shigellosis); water contact diseases (for example, schistosomiasis); and water vector diseases (for example, malaria, onchocerciasis) (Bartone, 1990). Many debilitating and easily preventable diseases are endemic in the world's large cities, including diarrhoea, dysentery, typhoid, intestinal parasites, and food poisoning. Whereas water-related diseases are a primary cause of infant and child mortality, mortality from air pollution typically occurs later in life. Relatively few deaths can be attributed directly to air pollution. However, millions suffer from respiratory infections (although the extent to which chemical air pollutants can reduce people's resistance to acute respiratory infections is not well understood), and many will die from some form of cancer caused or exacerbated by air pollution. Lead, for example, causes damage to bone marrow, liver and kidneys, and permanent neurological damage, especially in young children. Carbon monoxide can cause both neurological and cardiovascular damage. Indoor air pollution is particularly serious among low-income urban-dwellers, who commonly use fuelwood for cooking and heating in poorly ventilated housing. The impact of air pollution in workplaces is also very serious. Workers in quarries, cement plants, and rubber product factories, for example, are susceptible to silicosis, talcosis and stenosis, incurable lung diseases that may be fatal (Hardoy and Satterthwaite, 1989).

101. In most cases, the poorer residents of the world's large cities bear the human costs of the most debilitating impacts of environmental degradation. In many large cities, environmental pollution affects the poor more severely in part because many of them live at the periphery where manufacturing, processing and distilling plants are often built. The periphery is also where environmental protection is frequently the weakest.

102. In recent years, there has been a growing body of literature on the linkages among the urban environment, poverty and health (see Harpham and Molyneux, 2000). A notable aspect of many of these studies is the focus on differentials in health status or mortality rates between various population groups within cities. Not surprisingly, many of the studies found conditions in poorer areas of cities to be much worse than in the more affluent areas or even than the city average. Infant mortality rates in poorer areas, for example, were often four or more times higher than in more affluent areas, with much larger differentials apparent in the poorest district as compared with the most affluent district. Large differentials between rich and poor districts were also common in the incidence of many environmentally related diseases, for example, tuberculosis and typhoid (Satterthwaite, 1993).

Cities and sustainable development

103. In examining the linkages between urbanization and environmental issues, one central problem is that economic development exacerbates many environmental problems (for example, solid waste, automotive pollution) because the quantity of urban wastes generated per capita also tends to increase steadily with increased per capita income. Moreover, in recent decades, as incomes have risen in many countries and transport costs have declined, cities' "ecological footprints" have broadened. City-based consumers and industries have increasingly drawn on the carrying capacity of rural regions. This separates the environmental impact of the city's needs for natural resources from the city itself — to the point where city inhabitants and businesses are unaware of the environmental impact for which they are responsible (United Nations Centre for Human Settlements (Habitat), 1996).

104. In general, the countries with the largest draw per person on the world's natural capital (for example, with the highest levels of resource use, waste generation and greenhouse gas emissions) are also the countries with the highest proportion of their populations living in urban areas. Moreover, it is within urban areas that most of the world's resource use and waste generation are concentrated. Urban policies have very large implications in regard to future levels of greenhouse gas emissions and the use of most resources in each nation which is related both to the design and construction of urban buildings and to the spatial form that cities and urban systems take. Urban policies that encourage good practice in energy-efficient buildings and energy-efficient production units and that also ensure urban forms that are not increasingly dependent on high levels of private automobile use have a major role in de-linking high living standards from high greenhouse gas emissions (Hardoy, Mitlin and Satterthwaite, 2000). Thus, urban policies, plans and regulations should have a central role in any national strategy that promotes sustainable development, and city and municipal governments will be important actors in any successful strategy.

105. Cities can provide healthy, safe and stimulating environments for their inhabitants without imposing unsustainable demands on natural resources and ecosystems. A successful city, in this sense, is one that meets multiple goals, including healthy living and working environments for their inhabitants; water supply, provision of sanitation and solid waste collection, drains, paved roads and footpaths, and other forms of infrastructure essential for health; and an ecologically sustainable relationship between the demands of consumers and businesses and the resources, waste sinks and ecosystems on which they draw.

VII. Conclusions

106. The twentieth century has been a century of change. It has been a century of unprecedented world population growth, unprecedented world economic development and unprecedented change in the earth's physical environment.

107. From 1900 to 2000, world population grew from 1.6 billion to 6.1 billion persons, about 85 per cent of the growth having taken place in Asia, Africa and Latin America (United Nations, 1999a). And although population growth rates are slowing, United Nations population projections (United Nations, 1999a, 2000d) show that the world population is likely to exceed 8 billion people by 2030. As was the case with world population growth in the past, future growth is expected to be uneven: from 2000 to 2030, the more developed regions are expected to grow by less than 2 per cent, while the less developed regions would grow by over 40 per cent.

108. In 1900, about 86 per cent of the world population were rural dwellers and just 14 per cent were city dwellers (Matras, 1973); but by 2000, the share of the world population living in rural areas had declined to 53 per cent, while the number of urban-dwellers had risen to 47 per cent (United Nations, 2000d). By 2030, over three fifths of the world will be living in cities. Virtually all the population growth expected during 2000-2030 will be concentrated in the urban areas of the world.

109. The enormous expansion in the global production of goods and services driven by technological, social and economic change has allowed the world to sustain much larger total and urban populations, and vastly higher standards of living, than ever before. For example, from 1900 to 2000, world real GDP increased 20 to 40 times (DeLong, 1998), while world population increased close to 4 times and the urban population increased 13 times. The benefits accruing from the unprecedented growth of the world economy have occurred among both more developed and less developed countries, but growth has been unevenly distributed. The twentieth century's economic progress was disproportionately greater in the regions that were already more advanced at the start of that century.

110. Partially as a result of this economic expansion, substantial improvements have occurred in developed and developing countries alike in the quality and length of life. These achievements reflect progress in providing basic social services such as education and access to safe water and sanitation and have contributed to lowering levels of infant and child mortality and illiteracy, and raising life expectancy and school enrolment ratios. Although living standards have improved during the twentieth century throughout the world, the pace of improvement has varied among countries. In particular, AIDS and other emerging or re-emerging diseases in some

countries and economic and political dislocations in others have reversed past progress in improving health and mortality.

111. Relatively rapid and uneven population growth and economic development are occurring simultaneously with degradation of aspects of the earth's physical environment. For example, according to J. R. McNeill (2000), the twentieth century experienced topsoil loss equal to that of the previous 1,000 years. Total energy use during the 100 years of the twentieth century was 10 times that of the previous 1,000 years. World food production has increased at a faster rate than population and more food per capita is available now than ever before in world history; but the increasing scarcity and degradation of agricultural and other environmental resources cast serious doubts as to how long food production can surpass population growth. Throughout the world many fragile, biologically unique ecosystems, and the many species of plants and animals they contain, are threatened. Forest areas are diminishing, especially in tropical areas. Industrial pollution and harmful run-offs from agricultural production threaten the quality of water and air. Fresh water is already in short supply in some regions — approximately one third of the world's population lives in countries classified as experiencing moderate to severe water stress or scarcity — and future population growth will only increase the pressure on this renewable, but limited, resource. Emissions of CO_2 and other greenhouse gasses continue to mount.

112. Although scientists debate the exact numbers and rates of change, the general trends in population, environment and development noted in this report seem clear. As this report shows, what is more uncertain is the extent to which the size, growth and distribution of population have affected economic development and environmental trends. "World population monitoring, 1999" (United Nations, 1999b), in reviewing the relationship between population growth and economic development, concluded that the relationship was complex and varied over time and place, emphasizing the intermediary role of institutions with respect to the form and size of the population impact. The 1999 report reflected the consensus that slower population growth buys time for Governments and relevant institutions to respond to changing conditions.

113. A study by the Intergovernmental Panel on Climate Change (Watson, 2000) concluded that there was no doubt that human activities were disturbing the global carbon cycle through the combustion of fossil fuels and through land-use, land-use change and forestry activities. A recent study at Texas A&M University (Crowley, 2000) concluded that 75 per cent of global warming since 1900 had been due to human influences, "particularly to rising levels of carbon dioxide and other heat-trapping 'greenhouse gasses' that come from the burning of fuels and forests". Such human influences, however, stem mainly from modes of production, not from the size, growth and distribution of population. Moreover, humans may have a positive effect on the environment also: it was the combat of humans against the traditional environmental threats of bubonic plague, smallpox, tuberculosis and the like that led to the twentieth century gains in life expectancy and health.

114. This report indicates that population and demographic change interact with environmental change and economic development in a variety of ways. To begin with, it is clear that population affects and is affected by the environment and economic development. The challenge is to identify the complex interactions and effects of population, environment and development. To date, while some progress has been made, this challenge remains formidable for researchers and policy makers

alike. Sorting out the interactions among population, environment and economic development needs more and better data, particularly with respect to the environment.

115. While all the environmental problems discussed in this report are largely or entirely the result of human activities, they vary in the extent to which they can be linked directly to population size, growth or distribution. For example, growth in some types of pollution is primarily the by-product of rising per capita production and consumption in industrialized economies, where population has generally been growing slowly. Even for those environmental problems that are concentrated in countries with relatively rapid population growth, it is not necessarily the case that population increase is the main root cause, nor that halting population growth would resolve the problem: other social and technological "driving forces" are usually also contributing to environmental degradation. Nevertheless, other things being equal, continued increase in population plays an important role by increasing aggregate economic demand and hence the volume of pollution-causing production.

116. Population growth is generally regarded as the single most important force driving increases in agricultural demand. While most recent expert assessments are cautiously optimistic about the ability of global food production to keep up with demand for the next quarter-century or half-century, food insecurity, associated with poverty, is projected to persist for hundreds of millions of people. Nonetheless, FAO concluded (in an assessment prepared for the World Food Summit in 1996) that "with regard to poverty alleviation and food security, the inability to achieve environmentally sound and sustainable food production is primarily the result of human inaction and indifference rather than natural or social factors" (Food and Agriculture Organization of the United Nations, 1996a).

117. The need to feed a growing population is placing mounting stress on water supplies in many parts of the world. On a global basis, irrigation accounts for more than 70 per cent of fresh water taken from lakes, rivers and underground sources. While water is often inefficiently used, institutional mechanisms for implementing effective water management policies are often time-consuming and expensive and, in some cases, they are not viable options.

118. Population growth, through its effects on the expansion of cropland and the harvesting of wood for fuel, is an important factor contributing to deforestation in some areas, often tropical areas and areas rich in biodiversity. However, in several instances, it was government policies favouring the colonization of forested areas that accelerated the human settlement of the agricultural frontier and, in turn, caused rapid deforestation. Commercial logging is also a major cause of deforestation in some areas.

119. In rural areas of low-income countries, rapid population growth has often resulted in added pressures on agricultural land, resulting in land fragmentation and the reduction of yields. Such a process is at the root of a further cycle of environmental damage as the people who lack adequate land in one region migrate to ever more environmentally fragile areas in search of better chances of subsistence. Although the rural population of developing countries is expected to increase more slowly in the future than it did over the past 30 or 40 years, several regions already have very high population densities relative to available agricultural land. Consequently, even low levels of rural population growth are likely to result in added pressures on the rural environment. In those regions, the continued destruction of natural resources as a result of attempts to extend the agricultural frontier is very likely to continue or to accelerate in the future.

120. When considering responses to environmental problems, it is necessary to recognize that social-institutional factors can be as important as, if not more important than, technological ones. The general problem of managing locally scarce or fragile resources is not new. Many examples can be found where traditional societies developed communal rules for managing a scarce resource. Population growth has the potential to destabilize such communal arrangements, since rules that functioned adequately at a low population density may lead to overexploitation and/or pollution at a higher density. Successful adaptation may be possible — as, for instance, in the transition described by Boserup (1965) from shifting to settled agriculture — but it is important to note that changes in the social allocation of resources are likely to be required as part of such adaptation. Even though the overall social as well as environmental benefit to such organizational change may be large, the process may prove to be contentious and politically difficult.

121. The relationships between urbanization and environmental degradation are complicated, involving interactions with the natural and the human-made environment. The regional ecosystem (for example, coastal regions, arid regions, humid-tropical regions, mountainous regions) in which a city is located, for example, is often a critical determinant of environmental conditions. In the case of ambient pollution, for example, the vulnerability of large cities to the adverse impacts of vehicle emissions depends on certain natural features (for example, altitude, direction and speed of prevailing winds; amount of sunlight; precipitation and humidity). Economic development exacerbates many urban environmental problems (for example, solid waste, automotive pollution) because the quantity of urban wastes generated per capita also tends to increase steadily with increased incomes.

122. With globalization, and new and emerging technologies and modes of production and consumption, the relationships among population, environment and development have become issues of heightened concern for Governments, the international community and the average citizen. Population growth, structure and distribution are important aspects of environmental stress insofar as everyone requires the basic necessities of water, food, clothing, shelter and energy, which directly or indirectly affect the ecosystems (World Resources Institute, United Nations Environment Programme, United Nations Development Programme and World Bank, 2000). However, environmental stress is a matter not just of population change, but also of how and what people produce and consume now and in the future (World Resources Institute, United Nations Environment Programme, United Nations Development Programme and World Bank, 2000; United Nations, 1997b).

123. In his message to the Global Ministerial Environment Forum (Malmö, Sweden, 29-31 May 2000), the Secretary-General noted that "technological breakthroughs that are unimaginable today may solve some of the environmental challenges we face. But it would be foolish to count on them and to continue with business as usual" (United Nations Environment Programme, 2000). Government domestic programmes and effective international agreements, to curtail environmentally harmful activities, are essential. However, population pressures are contributing factors to environmental stress. Population and development policies — especially those relating to the size, growth and distribution of population — are necessary and vital components of the constellation of actions needed to ensure sustainable development and to safeguard the environment during the twenty-first century and beyond.

Annex I

Availability and quality of data

1. The present annex provides a concise summary of the sources, coverage and quality of data regarding population and the environment. The emphasis here is on general features and problems of the data rather than on particular indicators.

2. At the outset, it should be noted that errors and gaps in the availability of data are not the only problems in relating population to environmental variables. One difficulty is that the demographic data are likely to be compiled for geographical units different than those of the environmental indicators. Another is that the time periods for which geographically detailed data are available may differ between population and environmental indicators. One reason for this is that the data available for studying population and environment issues have been gathered for purposes other than the analysis of population-environmental interrelationships.

3. The empirical basis for estimating population size, growth and distribution is in general better than the one that exists for monitoring the environment. The primary data-collection systems for demographic and social information are population censuses, civil registration systems and sample surveys. These provide the primary bases for measuring demographic parameters such as size and growth of population, components of growth, birth and death rates and migration. Other relevant sources of demographic statistics include population registers (in some countries), immigration and emigration statistics and other "administrative" data such as school enrolment data and lists of eligible voters.

4. Population censuses are customarily taken decennially or quinquenially. The key features of a census include individual enumeration of all units, universality within a well-defined territory, simultaneity and periodicity. Population censuses can provide detailed data for small geographical areas. Censuses are a major source of many of the broad macrolevel indicators required to measure and monitor progress in the areas of population and development, public policy and legislative apportionment.

5. Sample surveys are an important tool for obtaining demographic data, particularly with respect to fertility and mortality. Because of their smaller scale, surveys provide an opportunity to study a topic in greater depth than that of a census, and they tend to employ better-qualified and better-trained enumerators. As a result, the data generated are generally found to be more accurate than census data. However, by their very nature, sample surveys that are nationally representative do not provide comprehensive information about small geographical areas, and, of course, survey estimates are subject to sampling error.

6. A variety of demographic techniques have been developed for evaluating data quality and deriving improved estimates (United Nations, 1983; 1988). In virtually all countries, the available population data are evaluated and, if necessary, adjusted for incompleteness and errors. The population data and projections discussed in this report have been evaluated and adjusted by the Population Division of the United Nations Secretariat as part of its preparations of the official United Nations population estimates and projections.

7. Recognition of the importance of environment statistics received an impetus from the United Nations Conference on the Human Environment (Stockholm, June 1972), which noted that environmental concerns had increasingly become the subject of mainstream socio-economic policies, at both the national and international levels. Twenty years later, a consensus was achieved at the United Nations Conference on Environment and Development (Rio de Janeiro, June 1992) that strategies of sustainable development should integrate environmental issues into development plans and policies. Such integration needs to be supported by resultant environmental and socio-economic data.

8. Among geographical regions and countries, large differences exist with regard to (a) the availability of relevant primary data in the area of environment, (b) the quality, comparability and frequency of data compilation and (c) the resultant quality of information systems. The amount of local, regional and global data in the form of country statistics, monitoring data, field measurements, satellite imagery and so forth is enormous, but the empirical base for the transformation and integration of raw data into meaningful information remains relatively weak. There are few

comprehensive international recommendations on the concepts and methods used in environment statistics. Data quality therefore depends on the reliability and comparability of the primary sources.

9. The *Global Environment Outlook 2000* (United Nations Environment Programme, 1999), prepared by the United Nations Environment Programme, provides a detailed analysis of the problems of data quality and availability. According to this survey, the major constraints affecting data issues are both institutional and technical. In most developing countries, the monitoring and data-collection infrastructure is handicapped owing to limitations in financial, technical and human resources. Those same constraints are also faced by regional and international organizations. The data management infrastructure in many countries is weak and data reporting is fragmented. In the absence of a central compiling system, environmental data remain scattered across many sectoral organizations and departments. Different agencies and organizations report their data for different geographical areas, thus hampering global and regional use and comparability of these aggregated data sets. Among the technical constraints, the lack of internationally accepted standards and definitions ranks highest. Other important factors include insufficient coverage, both in time and in space, of monitoring networks; different reporting periods; different and non-documented methods used to fill data gaps; and conceptual and technical difficulties of measurement, and differences in measurement method.

10. Despite the numerous inconsistencies and shortcomings, core environmental data sets are improving, expanding and becoming more easily accessible. Major initiatives have been launched to improve environmental observations and data collection, and to estimate the economic impact of environmental issues, ranging from ozone monitoring under the Montreal Protocol on Substances that Deplete the Ozone Layer and the three Global Observing Systems, to monitoring by non-governmental organizations of forests and coral reefs, to the establishment of guidelines for integrated economic and environmental accounting (United Nations, 1993b; United Nations and United Nations Environment Programme, 2000). There have also been efforts to improve coordination and cost-effectiveness, such as through the Integrated Global Observing Strategy. Another endeavour to monitor global ecosystems is the "Millennium Assessment of Global Ecosystems" (United Nations, 2000d), a process that was officially launched at the fifty-fifth session of the General Assembly in September 2000. The Millennium Assessment will assess on a global level the condition of five major ecosystems: forests, fresh water systems, grasslands, coastal areas and agro-ecosystems.

11. Gaps in data and scientific understanding undeniably make it difficult to achieve a consensus on actions needed to solve environmental problems. Nevertheless, it is widely acknowledged that environmental action may be warranted even when data and theories are incomplete. It is in this context that the precautionary principle, endorsed in 1992 at the United Nations Conference on Environment and Development, recognizes that action should not wait until all the scientific evidence is in place: "In the face of threats of irreversible environmental damage, lack of full scientific understanding should not be an excuse for postponing actions that are justified in their own right. The precautionary approach could provide a basis for policies relating to complex systems that are not yet fully understood and whose consequences of disturbances cannot yet be predicted" (Agenda 21, para. 35.3).

Annex II

Theories and frameworks for modelling the impact of population growth on the physical environment

1. Since ancient times, statesmen and philosophers have written about the balance between population and natural resources and opined on the concept of an optimum number of people (United Nations, 1973a). These ancient writings anticipated aspects of the more formal concepts developed later and contained seeds of certain ideas that figure prominently in modern theoretical works.

2. The works of ancient Chinese philosophers, including Confucius and his school, contain some concept of optimum population at the local level. It was posited that the government was responsible for maintaining an ideal balance between land and population by sponsoring migrations from or to overpopulated or underpopulated areas. Plato and Aristotle were alert to the necessity of population's being self-sufficient in food, and warned that the fact that cultivated land could not be expanded rapidly enough to match rapid population growth would lead to overpopulation and poverty. Although early and medieval Christian doctrines generally considered population issues from a moral and ethical standpoint, some writers regarded the excessive growth of the known world population as the cause of poverty and suffering and attributed to nature the ability to re-establish the balance between population and resources through pestilence, famine and war.

3. One should mention that not all theorists saw population growth in a negative light. In particular, mercantilist ideas in Europe during the seventeenth and eighteenth century reflected the positive aspects of large and growing populations and favoured policies to encourage marriage and large families.

4. For the last two centuries, the Malthusian perspective has shaped to a large extent the debate on population-development relationships. Both its advocates and foes shared concerns about the balance among demographic trends (essentially population growth), natural resources and economic growth and poverty. Whereas initially the debate focused on Great Britain in the midst of its industrial revolution, in the second half of the twentieth century that debate widened in scope to include the availability of arable land for food production by and for the poor in the developing countries who constitute the majority of mankind. Yet, framing the population-environment relationships in terms of per capita availability of resources has led to opposing perspectives. On the one hand, the "limits to growth" perspective considers population growth fundamentally detrimental to the global system (Meadows and others, 1972; Meadows, Meadows and Randers, 1992; Brown, Gardner and Halweil, 1999); on the other hand, there is the view that population growth is a positive impetus for technological progress (Boserup, 1965, 1976, 1981; Simon, 1981, 1990, 1996).

5. The concept of land-carrying capacity provides a framework for studying the relationship between population and renewable resources. In order to widen the concept, carrying capacity is sometimes defined as the number of people that can be supported for the foreseeable future without degrading the physical, ecological, cultural and social environment (Cohen, 1995). A narrower and highly technical approach to carrying capacity was applied in the early 1980s to systematically assess the maximum population that could be supported in a sustainable way by the national agriculture of developing countries (Higgins and others, 1983; 1984; Food and Agriculture Organization of the United Nations, 1994; Heilig, 1999). The concept of carrying capacity has gained renewed attention within the context of sustainable development which interprets food security as the result of a significant and sustainable increase in agricultural production, and of the achievement of substantial improvements in people's food entitlement (Ruttan, 1996).

6. Natural and social scientists have introduced a variety of models to study the population-environment links, including several decomposition (or multiplicative) models (Commoner, 1991; Bongaarts, 1992; Ehrlich and Holdren, 1971, 1974; Ehrlich and Ehrlich, 1992; Harrison, 1992). In these models, total environmental impacts are seen as a product of population size, the level of affluence or per capita consumption/production, and the level of environmentally damaging technology. The empirical applications of this model have focused on the increase

in use of specific resources or emissions of particular pollutants associated with the increase of supply of particular goods or services. Consequently, the results with respect to the role of demographic factors vary.

7. The logic of the multiplicative models has been applied in the complex modelling of global climate change. Population size and growth invariably feature among the numerous variables involved in the analysis (International Panel on Climate Change, 1990; Leggett and others, 1992; Pitcher, forthcoming). Non-linear relationships based on complex feedback loops linking demographic, economic and environmental variables were the characteristic feature of the Club of Rome global models. Their value was limited by a paucity of empirical data that were too often supplemented by assumptions. Currently, attempts are under way to overcome this major drawback using region- and country-specific frameworks. For instance, the Economic Commission for Africa (ECA) designed a population-environment-development-agriculture (PEDA) model which links population change, environment, socio-economic development and agriculture, to demonstrate the impact of different policy options on food security in the ECA region (United Nations, Economic Commission for Africa, 1999).

8. A large body of research traces changes in the ecosystem with respect to demographic growth through transformations of social, cultural and institutional factors. Those transformations could have positive or destructive effects on the environment depending on institutional realities — market conditions, property rights, land distribution, taxes and subsidies on various types of production and consumption. Generalizing across societies and stages of development, institutional analyses assert that population growth decreases the price of labour relative to land and therefore induces a redefinition of property rights in respect of land and a rearrangement of labour relations. As a result, a whole array of rural institutions evolve to minimize the costs of initiating and enforcing contracts among economic agents (McNicoll and Cain, 1989) even as the quality of the environment is compromised. The concept of population-induced innovations was refined by incorporating the role of incomplete information and imperfect markets typical of the rural settings of developing countries, where population pressure and production costs (for example, seasonality, yield risks, market price risks, timing uncertainty) ultimately lead to adaptive change in rural institutions (Rosenzweig, Binswanger and McIntire, 1988).

9. The correlation of rapid population growth with environmental degradation and, in several societies, with destabilization rather than constructive transformation of property rights, has called into question the postulate that technological progress and agricultural innovation are a function of population growth. Institutional analysis was instrumental in explaining how rapid population growth in the second half of the twentieth century had, in several settings, played a negative role by inducing decay of the old institutions while preventing development of modern property rights. In societies with relatively well-defined land property rights and high population pressure on arable land — as in South-central Asia, Central America and the Caribbean — population growth led to land fragmentation and, ultimately, to land overuse; but rapid population growth was also found to be destructive of the fragile ecological equilibria under conditions of loosely defined land ownership and relative abundance of land typical of several sub-Saharan countries (Cleaver and Schreiber, 1994).

10. The theory of multiphasic response (Davis, 1963; Bilsborrow, 1987; Bilsborrow and Geores, 1994) attempts to integrate into a comprehensive framework, responses to increasing population pressure. One weakness of this approach also lies in its elasticity. Because the responses to growing population pressure can be simultaneous, the extent of any one of the responses occurring — fertility decline, land intensification or land extensification — depends upon the others and hence upon all economic and institutional factors influencing those responses. Therefore, the theory has little power to predict which response is likely to occur under particular circumstances.

11. Whether mediated by technology or by markets and social institutions, population growth is one factor in the triad of population, environment and development. The absence of a comprehensive model encompassing all facets of the triad is a testimony as much of the complexity and dynamism of the relationships, as of the lack of data to design and test such a model.

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